

Certification of Translation
(Japanese Patent Application No. 2004-025837)

I, the undersigned, Yoko TAKAHASHI residing at the Front Shonan Fujisawa 704, 972-1 Fujisawa, Fujisawa-shi, Kanagawa 251-0052, JAPAN do solemnly and sincerely declare that I am well acquainted with the Japanese language and the English language and that the attached English translation of the Japanese Patent Application No. 2004-025837 filed February 2, 2004 is an accurate translation to the best of my knowledge and belief from the Japanese language into the English language.

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[DOCUMENT NAME] CLAIMS

[Claim 1] A stage drive method in which a first stage and a second stage are independently driven within an area in a two-dimensional plane of a predetermined range including a
5 first area that includes a first position where liquid is locally supplied and a second area located on one side of the first area in a first axis direction, wherein

 during a transition from a first state in which one stage of the first stage and the second stage is positioned
10 at the first area to a second state in which the other stage is positioned at the first area, both stages are simultaneously driven in a second axis direction intersecting the first axis direction in a state where both stages are close together in the second axis direction or a state where
15 both stages are in contact in the second axis direction is maintained.

[Claim 2] The stage drive method of Claim 1 wherein
 the first stage and the second stage are separately driven by a set of linear actuators that can engage freely
20 detachable to both the first stage and the second stage and each of that can drive a specific stage in an engaged state in at least the second axis direction, and

 during the transition, one stage of the first stage and the second stage is in an engaged state with one linear
25 actuator of the set of linear actuators and the other stage is in an engaged state with the other linear actuator, and after the transition, the engagement between both stages and the linear actuators are released respectively and then the

one stage engages with the other linear actuator and the other stage engages with the one linear actuator.

[Claim 3] A stage drive method in which a first stage is driven within an area in a two-dimensional plane of a predetermined range including a first area that includes a first position and a second area located on one side of the first area in a first axis direction where liquid is locally supplied, and a second stage is driven within an area of a predetermined range including the first area and a third area located on the other side of the first area in the first axis direction,
10 wherein

15 during a transition from a first state in which one stage of the first stage and the second stage is positioned at the first area to a second state in which the other stage is positioned at the first area, both stages are simultaneously driven in the first axis direction while a state where both stages are close together in the first axis direction or a state where both stages are in contact in the first axis direction is maintained.

20 [Claim 4] The stage drive method in any one of Claims 1 to 3 wherein

25 during the transition, the liquid continues to be retained on the stage positioned at the first area.

[Claim 5] The stage drive method in any one of Claims 1 to 4 wherein

measurement beams are irradiated on reflection surfaces of a first mirror and a second mirror, which are respectively arranged on the first stage and the second stage

on a surface besides the surface on the side where both stages are close or are in contact during the transition, and the position of the first and second stages is controlled based on reflection beams from the reflection surfaces of the first 5 mirror and the second mirror.

[Claim 6] An exposure apparatus that supplies a liquid to a space between a projection optical system and a substrate and exposes the substrate with an energy beam via the projection optical system and the liquid, the apparatus comprising:

10 a first stage that is movable within an area of a predetermined range including a first area that includes a first position directly below the projection optical system where the liquid is supplied and a second area located on one side of the projection optical system in a first axis 15 direction;

 a second stage that is movable within an area of a predetermined range including the first area and a third area located on the other side of the projection optical system in the first axis direction;

20 a stage drive system that drives the first stage and the second stage, and simultaneously drives both stages in the first axis direction while a state where both stages are close together in the first axis direction or a state where both stages are in contact in the first axis direction is 25 maintained, during a transition from a first state in which one stage of the first stage and the second stage is positioned in the first area to a second state in which the other stage is positioned in the first area;

a first mark detection system arranged above the second area that detects a mark located on the first stage; and a second mark detection system arranged above the third area that detects a mark located on the second stage.

5 [Claim 7] The exposure apparatus of Claim 6 wherein the first stage and the second stage are both stages on which substrates can be mounted.

[Claim 8] An exposure apparatus that supplies a liquid to a space between a projection optical system and a substrate and 10 exposes the substrate with an energy beam via the projection optical system and the liquid, the apparatus comprising:

a first stage that is movable within an area of a predetermined range including a first area that includes a first position directly below the projection optical system 15 where the liquid is supplied and a second area located on one side of the first area in a first axis direction;

a second stage that is movable within an area of a predetermined range including the first area and a third area located on the other side of the first area in the first axis 20 direction; and

a stage drive system that drives the first stage and the second stage, and simultaneously drives both stages in the first axis direction while a state where both stages are close together in the first axis direction or a state where 25 both stages are in contact in the first axis direction is maintained, during a transition from a first state in which one stage of the first stage and the second stage is positioned in the first area to a second state in which the other stage

is positioned in the first area.

[Claim 9] The exposure apparatus of Claim 8 wherein
on the second stage, at least one of a part of a sensor
that receives the energy beam via the projection optical system
5 and a fiducial mark plate on which at least one fiducial mark
is formed is arranged.

[Claim 10] The exposure apparatus in one of Claims 8 and 9
wherein

the second stage is used for measurement using
10 photodetection results of the energy beam via the projection
optical system and the liquid.

[Claim 11] The exposure apparatus in any one of Claims 8 to
10 wherein

when exposing a substrate with the energy beam, the
15 stage drive system drives the first stage based on at least
a part of the measurement results using the second stage.

[Claim 12] The exposure apparatus of Claim 11 wherein

the stage drive system drives each of the stages so
that measurement using the second stage is being performed,
20 while exchange of a substrate on the first stage is being
performed.

[Claim 13] An exposure apparatus that supplies a liquid to
a space between a projection optical system and a substrate
and exposes the substrate via the projection optical system
25 and the liquid, the apparatus comprising:

a first stage that is movable within an area of a
predetermined range including a first area that includes a
first position directly below the projection optical system

where the liquid is supplied and a second area located on one side of the first area in a first axis direction;

a second stage that is movable independent from the first stage within an area of a predetermined range including

5 the first area and the second area; and

a stage drive system that drives the first stage and the second stage, and simultaneously drives both stages in a second axis direction intersecting the first axis direction while a state where both stages are close together in the second

10 axis direction and a state where both stages are in contact in the second axis direction is maintained, during a transition from a first state in which one stage of the first stage and the second stage is positioned in the first area to a second state in which the other stage is positioned in the first area.

15 [Claim 14] The exposure apparatus according to Claim 13 wherein

the stage drive system includes a set of linear actuators that drive the first stage and the second stage separately, which can engage freely detachable to both the first stage and the second stage and each of which can drive 20 a specific stage in an engaged state in the second axis direction.

[Claim 15] The exposure apparatus according to Claim 14, the apparatus further comprising:

a switching unit that switches a state where one stage 25 of the first stage and the second stage is in an engaged state with one linear actuator of the set of linear actuators and the other stage is in an engaged state with the other linear actuator to a state where the one stage engages with the other

linear actuator and the other stage engages with the one linear actuator after the transition.

[Claim 16] The exposure apparatus according to any one of Claims 13 to 15 wherein

5 the first stage and the second stage are both stages on which substrates can be mounted, and the apparatus further comprises:

10 a mark detection system disposed in the second area that detects a mark located on a specific stage, which is one of the first stage and the second stage positioned directly under the mark detection system.

[Claim 17] The exposure apparatus in any one of Claims 6 to 16 wherein

15 the stage drive system maintains the state where the first stage and the second stage are close together during the transition, and

20 in at least one of the first stage and the second stage, a suppressing member is arranged so as to suppress leakage of the liquid from a gap between the stages by being positioned in the gap between the stages during the transition.

[Claim 18] The exposure apparatus of Claim 17 wherein

 the suppressing member includes at least one of a seal member and a water-repellent coating.

[Claim 19] An exposure apparatus that supplies a liquid to a space between a projection optical system and a substrate and exposes the substrate via the projection optical system and the liquid, the apparatus comprising:

 a first stage that is movable within an area including

a first area that includes a first position directly below the projection optical system where the liquid is supplied and an area different from the first area;

5 a second stage that is movable independent from the first stage within the area including the first area and the area different from the first area;

10 a stage drive system that drives the first stage and the second stage, and simultaneously drives both stages in a predetermined direction while a state where both stages are close together in the predetermined direction is maintained, during a transition from a first state in which one stage of the first stage and the second stage is positioned in the first area to a second state in which the other stage is positioned in the first area; and

15 a suppressing member arranged in at least one of the first stage and the second stage, so as to suppress leakage of the liquid from a gap between the stages by being positioned in the gap between the stages during the transition.

[Claim 20] The exposure apparatus of Claim 19 wherein
20 the suppressing member includes at least one of a seal member and a water-repellent coating.

[Claim 21] The exposure apparatus in any one of Claims 6 to 20 wherein

25 during the transition, the liquid continues to be held in the space between the projection optical system and the stage positioned in the area that include the first position.

[Claim 22] The exposure apparatus in any one of Claims 6 to 21, the apparatus further comprising:

a first mirror and a second mirror arranged on the first stage and the second stage, respectively, on a surface besides the surface on the side where both stages are close together or are in contact on the transition; and

5 an interferometer that measures the position of the first stage and the second stage by irradiating measurement beams respectively on reflection surfaces of the first mirror and the second mirror, based on reflection beams from the reflection surfaces of the first mirror and the second mirror.

10 [Claim 23] A device manufacturing method that includes a lithography step in which a substrate is exposed with the energy beam, using the exposure apparatus according to any one of Claims 6 to 22.

[DOCUMENT NAME] SPECIFICATION**[TITLE OF INVENTION] STAGE DRIVE METHOD, EXPOSURE APPARATUS,
AND DEVICE MANUFACTURING METHOD****[TECHNICAL FIELD]**

5 [0001] The present invention relates to stage drive methods, exposure apparatus, and device manufacturing methods, and more particularly to a stage drive method in which two stages movable in an area including a first area that includes a first position within a two-dimensional plane where a liquid
10 is locally supplied are driven, an exposure apparatus that supplies liquid in a space between a projection optical system and a substrate and exposes the substrate via the projection optical system and the liquid, and a device manufacturing method that uses the exposure apparatus.

15 [BACKGROUND ART]

20 [0002] Conventionally, in a lithography process for manufacturing electronic devices such as a semiconductor device (such as an integrated circuit), a liquid crystal display device or the like, a reduction projection exposure apparatus by the step-and-repeat method that transfers an image of a pattern of a mask or a reticle (hereinafter generally referred to as a 'reticle') onto each of a plurality of shot areas on a photosensitive substrate such as a wafer coated with a resist (photosensitive agent), a glass plate, or the
25 like (hereinafter generally referred to as a 'substrate' or a 'wafer') via a projection optical system, or a projection exposure apparatus by the step-and-scan method (the so-called scanning stepper (also referred to as a scanner)) are mainly

used.

[0003] Resolution R of the projection optical system that the projection exposure apparatus has can be expressed as in equation (1) below by Rayleigh's formula.

5 [0004] $R = k_1 \cdot \lambda / NA$ (1)

In this case, λ is the exposure wavelength, NA is the numerical aperture of the projection optical system, and k_1 is a process factor. According to equation (1), the equation becomes higher when the exposure wavelength used (the 10 wavelength of the exposure light) becomes shorter or when the numerical aperture or the projection optical system (NA) becomes larger. Therefore, as the integrated circuit becomes finer, the exposure wavelength used in the projection exposure apparatus is becoming shorter year by year, and nowadays, 15 exposure apparatus that uses the ArF excimer laser (wavelength 193 nm) whose wavelength is shorter than the KrF excimer laser (wavelength 248 nm) is also put to practical use. Further, the numerical aperture of the projection optical system is gradually increasing.

20 [0005] When performing exposure, the depth of focus (DOF) is also important as well as the resolution. Depth of focus δ can be expressed as in equation (2) below.

[0006] $\delta = k_2 \cdot \lambda / NA^2$ (2)

25 [0007] In this case, k_2 is a process factor. From equations (1) and (2), it can be seen that when exposure wavelength λ is shortened and numerical aperture NA is increased (a larger NA) in order to increase resolution R, depth of focus δ becomes narrower. In the projection exposure

apparatus, when exposure is performed, because the surface of the wafer is made to conform to the image plane of the projection optical system by the auto-focus method, depth of focus δ should preferably be wide to some extent.

5 [0008] However, due to the shorter wavelength of the exposure light and the larger numerical aperture of the projection optical system described above, the depth of focus is becoming narrower. Further, the exposure wavelength is presumed to be much shorter in the future; however, in such
10 a case, the depth of focus may become so small that margin shortage may occur during the exposure operation.

[0009] Therefore, as a method of substantially shortening the exposure wavelength while increasing (widening) the depth of focus when compared with the depth
15 of focus in the air, the exposure apparatus that uses the immersion method is recently gathering attention. As such an exposure apparatus using the immersion method, the apparatus that performs exposure in a state where the space between the lower surface of the projection optical system and the wafer
20 surface is locally filled with liquid such as water or an organic solvent is known (for example, refer to Patent Document 1 below). According to the exposure apparatus of Patent Document 1, the resolution can be improved by making use of the fact that the wavelength of the exposure light in the liquid
25 becomes $1/n$ of the wavelength in the air (n is the refractive index of the liquid which is normally around 1.2 to 1.6), and the depth of focus can be also substantially increased n times when compared with the case where the same resolution is

obtained by a projection optical system (supposing that such a projection optical system can be made) that does not employ the immersion method. That is, the depth of focus can be substantially increased n times than in the air.

5 [0010] However, in the exposure apparatus according to Patent Document 1, the liquid has to be recovered once at the point before the wafer stage moves away from under the projection optical system in order to prevent the water from leaking during wafer exchange, so as to change the state of
10 the space between the lower surface of the projection optical system and the wafer surface from a wet state to a dry state. However, when the recovery and the supply of the liquid is performed each time the wafer is exchanged, it is certain that the time required for the recovery and supply of the liquid
15 will cause a decrease in throughput of the exposure apparatus.

[0011] Further, when changed from the wet state into the dry state in the manner described above, in the case the dry state continues, on the surface of the optical member constituting the projection optical system on the lowest end, which is also referred to as a front (lens) (such as a lens or a glass plate) or an optical member (e.g. a prism or the like), which is a member configuring an autofocus mechanism, arranged in the vicinity of the tip lens, there was the risk of water stains (water marks) being generated on the surface.
20 This water stain generation may lead to a decrease in transmittance or may be the cause of flare, and furthermore it may be a cause of deterioration in other image-forming performances in the projection optical system. Further, in
25

the case water marks are generated on the prism or the like referred to above, there was the risk of the plane conforming accuracy decreasing when the surface of the wafer was made to conform to the image plane of the projection optical system.

5 Further, when many water marks are generated, the tip lens or the optical member has to be replaced, however, the time required for the replacement also becomes the cause of decreasing the throughput of the exposure apparatus.

[0012] Patent Document 1: the Pamphlet of
10 International Publication Number WO99/49504

[DISCLOSURE OF INVENTION]

[MEANS FOR SOLVING THE PROBLEMS]

[0013] The present invention has been made in
15 consideration of the situation described above, and according to a first aspect of the present invention, there is provided a first stage drive method in which a first stage (WST1') and a second stage (WST2') are independently driven within an area in a two-dimensional plane of a predetermined range including
20 a first area that includes a first position where liquid (Lq) is locally supplied and a second area located on one side of the first area in a first axis direction, wherein on a transition from a first state in which one stage of the first stage and the second stage is positioned at the first area to a second
25 state in which the other stage is positioned at the first area, both stages are simultaneously driven in a second axis direction intersecting the first axis direction while a state where both stages are close together in the second axis

direction or a state where both stages are in contact in the second axis direction is maintained.

[0014] In this case, 'a state where both stages are close together' refers to a state where both stages are close enough so that the liquid does not leak from between both stages, and the permissible value of the distance between both stages differs depending on the material of both stages and/or the type of the liquid. In the description, the expression 'a state where both stages are close together' is used in the sense described above.

[0015] According to this method, when independently driving the first stage and the second stage within the area in a two-dimensional plane of a predetermined range including the first area that includes the first position where liquid 15 is locally supplied and the second area located on one side of the first area in the first axis direction, in the case of a transition from the first state where one stage of the first stage and the second stage is positioned at the first area to the second state where the other stage is positioned 20 at the first area, the first stage and the second stage are simultaneously driven in the second axis direction intersecting the first axis direction while a state where the first stage and the second stage are close in the second axis direction or a state where the first stage and the second stage 25 are in contact in the second axis direction is maintained. This allows the transition from the first state to the second state, in a state where the liquid is supplied on a specific stage at the first position, without the liquid leaking from

the gap between both stages. That is, it becomes possible to perform a transition from a state where the liquid is held on one stage to a state where the liquid is held on the other stage, without going through the process of fully recovering 5 the liquid and supplying the liquid again. Accordingly, it becomes possible to perform the transition from the first state to the second state within a short period.

[0016] According to a second aspect of the present invention, there is provided a second stage drive method in 10 which a first stage (WST1, WST) is driven within an area in a two-dimensional plane of a predetermined range including a first area that includes a first position where liquid is locally supplied and a second area located on one side of the first area in a first axis direction, and a second stage (WST2, 15 MST) is driven within an area of a predetermined range including the first area and a third area located on the other side of the first area in the first axis direction, wherein on a transition from a first state in which one stage of the first stage and the second stage is positioned at the first 20 area to a second state in which the other stage is positioned at the first area, both stages are simultaneously driven in the first axis direction while a state where both stages are close together in the first axis direction or a state where both stages are in contact in the first axis direction is 25 maintained.

[0017] According to this method, when driving the first stage within the area in the two-dimensional plane of a predetermined range including the first area that includes

the first position where liquid is locally supplied and the second area located on one side of the first area in the first axis direction and also driving the second stage within the area of a predetermined range including the first area and
5 the third area located on the other side of the first area in the first axis direction, in the case of a transition from the first state where one stage of the first stage and the second stage is positioned at the first area to the second state where the other stage is positioned at the first area,
10 both stages are simultaneously driven in the first axis direction while a state where both stages are close together in the first axis direction or a state where both stages are in contact in the first axis direction is maintained. This allows the transition from the first state to the second state,
15 in a state where the liquid is supplied on a specific stage at the first position, without the liquid leaking from the gap between both stages. That is, it becomes possible to perform a transition from a state where the liquid is held on one stage to a state where the liquid is held on the other
20 stage, without going through the process of fully recovering the liquid and supplying the liquid again. Accordingly, it becomes possible to perform the transition from the first state to the second state within a short period.

[0018] According to a third aspect of the present invention, there is provided a first exposure apparatus that supplies a liquid (Lq) to a space between a projection optical system (PL) and a substrate (W) and exposes the substrate with an energy beam (IL) via the projection optical system and the

liquid, the apparatus comprising: a first stage (WST1) that can be moved within an area of a predetermined range including a first area directly below the projection optical system where the liquid is supplied and a second area located on one side 5 of the projection optical system in a first axis direction; a second stage (WST2) that can be moved within an area of a predetermined range including the first area and a third area located on the other side of the projection optical system in the first axis direction; a stage drive system (20, 124) 10 that drives the first stage and the second stage, as well as simultaneously drives both stages in the first axis direction while a state where both stages are close together in the first axis direction or a state where both stages are in contact in the first axis direction is maintained, on a transition 15 from a first state in which one stage of the first stage and the second stage is positioned at the first area to a second state in which the other stage is positioned at the first area; a first mark detection system (ALG1) arranged above the second area that detects a mark located on the first stage; and a 20 second mark detection system (ALG2) arranged above the third area that detects a mark located on the second stage.

[0019] According to this apparatus, when a transition is performed from the first state where one stage is positioned at the first area including the first position directly below 25 the projection optical system where the liquid is supplied to a second state where the other stage is positioned at the first area, the stage drive system simultaneously drives the first stage and the second stage in the first axis direction

while a state where the first stage and the second stage are close together in the first axis direction and a state where both stages are in contact in the first axis direction is maintained. This allows the transition from the first state 5 to the second state, in a state where the liquid is supplied between the projection optical system the specific stage located directly under the projection optical system, without the liquid leaking from the gap between both stages. That is, during the period after the exposure operation of the substrate 10 via the projection optical system and the liquid on the one stage side has been performed until the exposure operation of the substrate via the projection optical system and the liquid on the other stage side begins, it becomes possible to perform the transition from a state where the liquid is held in the space between the one stage and the projection 15 optical system to a state where the liquid is held in the space between the other stage and the projection optical system, without going through the process of fully recovering the liquid and supplying the liquid again. Accordingly, the time 20 from completing the exposure operation on one stage side until the beginning of exposure operation on the other stage side can be reduced and it becomes possible to improve the throughput. Further, because the liquid constantly exists on the image plane side of the projection optical system, 25 generation of water stains (water marks) on the optical members on the image plane side of the projection optical system can be effectively prevented. Further, because the exposure operation of the substrate in the first stage side and the

mark detection operation (alignment operation) of the substrate on the second stage by the second mark detection system, and the exposure operation of the substrate in the second stage side and the mark detection operation (alignment operation) of the substrate on the first stage by the first mark detection system can each be performed in parallel, an improvement in the throughput can be expected when comparing the case where the substrate exchange, mark detection (alignment), and exposure operation are performed sequentially, using a single stage.

[0020] According to a fourth aspect of the present invention, there is provided a second exposure apparatus that supplies a liquid (L_q) to a space between a projection optical system (PL) and a substrate (W) and exposes the substrate with an energy beam (IL) via the projection optical system and the liquid, the apparatus comprising: a first stage (WST) that can be moved within an area of a predetermined range including a first area directly below the projection optical system where the liquid is supplied and a second area located on one side of the first area in a first axis direction; a second stage (MST) that can be moved within an area of a predetermined range including the first area and a third area located on the other side of the first area in the first axis direction; and a stage drive system (20, 80, 81, 82, 83, 84, 85) that drives the first stage and the second stage, and simultaneously drives both stages in the first axis direction while a state where both stages are close together in the first axis direction or a state where both stages are in contact in the first axis

direction is maintained, on a transition from a first state in which one stage of the first stage and the second stage is positioned at the first area to a second state in which the other stage is positioned at the first area.

5 [0021] According to this apparatus, when a transition is performed from the first state where one stage is positioned at the first area including the first position directly below the projection optical system where the liquid is supplied to a second state where the other stage is positioned at the
10 first area, the stage drive system simultaneously drives the first stage and the second stage in the first axis direction while a state where both stages are close together in the first axis direction or a state where both stages are in contact in the first axis direction is maintained. This allows the
15 transition from the first state to the second state, in a state where the liquid is held in the space between the projection optical system and the specific stage directly below the projection optical system, without the liquid leaking from the gap between both stages. That is, during the period after
20 the exposure operation of the substrate in the first stage side via the projection optical system and the liquid has been performed until the measurement directly under the projection optical system on the second stage side begins, it becomes possible to perform the transition from a state where the
25 liquid is held in the space between the first stage and the projection optical system to a state where the liquid is held in the space between the second stage and the projection optical system, without going through the process of fully

recovering the liquid and supplying the liquid again. Further, the same applies to after the measurement has been completed on the second stage until the exposure begins on the first stage. Accordingly, the time from completing the exposure 5 operation on the first stage side until the beginning of measurement operation on the second stage side and the time from completing the measurement operation on the second stage side until the beginning of exposure operation on the first stage side can be reduced, and it becomes possible to improve 10 the throughput. Further, because the liquid constantly exists on the image plane side of the projection optical system, generation of water stains (water marks) on the optical members on the image plane side of the projection optical system can be effectively prevented. Further, the exposure operation of 15 the substrate in the first stage side and the measurement operation in the second stage side can be performed in parallel, depending on the measurement operation.

[0022] According to a fifth aspect of the present invention, there is provided a third exposure apparatus that 20 supplies a liquid to a space between a projection optical system (PL) and a substrate (W) and exposes the substrate via the projection optical system and the liquid, the apparatus comprising: a first stage (WST1') that can be moved within an area of a predetermined range including a first area that 25 includes a first position directly below the projection optical system where the liquid is supplied and a second area located on one side of the first area in a first axis direction; a second stage (WST2') that can be moved independent from the

first stage within an area of a predetermined range including the first area and the second area; and a stage drive system (20, 124A) that drives the first stage and the second stage, and simultaneously drives both stages in a second axis direction intersecting the first axis direction while a state where both stages are close together in the second axis direction and a state where both stages are in contact in the second axis direction is maintained, on a transition from a first state in which one stage of the first stage and the second stage is positioned at the first area to a second state in which the other stage is positioned at the first area.

[0023] According to this apparatus, when a transition is performed from the first state where one stage is positioned at the first area that includes the first position directly below the projection optical system to which the liquid is supplied to the second state where the other stage is positioned at the first area, the stage drive system simultaneously drives the first stage and the second stage in the second axis direction (the direction intersecting the first axis direction in which the first area and the second area are arranged) while a state where the first stage and the second stage are close together in the second axis direction or a state where both stages are in contact in the second axis direction is maintained. This allows the transition from the first state to the second state, in a state where the liquid is held in the space between the projection optical system and the specific stage directly below the projection optical system, without the liquid leaking from

the gap between both stages. That is, during the period after the exposure operation of the substrate on one stage side via the projection optical system and the liquid has been performed until the exposure operation of the substrate on the other 5 stage side via the projection optical system and the liquid begins, it becomes possible to perform the transition from a state where the liquid is held in the space between one stage and the projection optical system to a state where the liquid is held in the space between the other stage and the projection 10 optical system, without going through the process of fully recovering the liquid and supplying the liquid again.

Accordingly, the time from when the exposure operation of the substrate in the one stage side has been completed until the beginning of the exposure operation in the other stage side 15 can be reduced, which allows the throughput to be improved. Further, because the liquid constantly exists on the image plane side of the projection optical system, generation of water stains (water marks) on the optical members on the image plane side of the projection optical system can be effectively 20 prevented.

[0024] According to a sixth aspect of the present invention, there is provided a fourth exposure apparatus that supplies a liquid (Lq) to a space between a projection optical system (PL) and a substrate (W) and exposes the substrate via 25 the projection optical system and the liquid, the apparatus comprising: a first stage (WST1, WST1', WST) that can be moved within an area including a first area that includes a first position directly below the projection optical system where

the liquid is supplied and an area different from the first area; a second stage (WST2, WST2', MST) that can be moved independent from the first stage within the area including the first area and the area different from the first area;

5 a stage drive system that drives the first stage and the second stage, and simultaneously drives both stages in a predetermined direction while a state where both stages are close together in the predetermined direction is maintained, on a transition from a first state in which one stage of the

10 first stage and the second stage is positioned at the first area to a second state in which the other stage is positioned at the first area; and a suppressing member (93) arranged in at least one of the first stage and the second stage, so as to suppress leakage of the liquid from a gap between the stages

15 by being positioned in the gap between the stages on the transition.

[0025] According to this apparatus, when a transition is performed from the first state where one stage of the first stage and the second stage that can be moved within the area 20 including the first area directly below the projection optical system and the area different from the first area is positioned at the first area, to the second state where the other stage is positioned at the first area, because both stages are in a state close together in the first axis direction and are 25 also simultaneously driven in the predetermined direction in a state where the suppressing member for suppressing liquid leakage arranged in at least one of the first stage and second stage is positioned in the gap between the stages, liquid

leakage from between the stages can be suppressed as much as possible. By keeping both stages from coming into contact in the manner described above, decrease in position control accuracy can be suppressed, and it also becomes possible to 5 avoid deformation or the like caused by both stages bumping into each other as much as possible.

[0026] Further, in a lithography process, by exposing the substrate with the energy beam using each of the first to fourth exposure apparatus of the present invention, the 10 device pattern can be transferred onto the substrate with good accuracy, and as a consequence, the productivity of microdevices with high integration can be improved. Accordingly, it can also be said further from another aspect that the present invention is a device manufacturing method, 15 using any one of the first to fourth exposure apparatus of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0027]

20 <<First Embodiment>>

A first embodiment of the present invention will be described below, referring to FIGS. 1 to 10.

[0028] FIG. 1 schematically shows the entire configuration of an exposure apparatus 100 related to the first 25 embodiment. Exposure apparatus 100 is a projection exposure apparatus by the step-and-scan method, that is, the so-called scanning stepper (also called a scanner). Exposure apparatus 100 is equipped with illumination system 10, a reticle stage

RST that holds a reticle R serving as a mask, a projection unit PU, a wafer stage unit 50 that has wafer stages WST1 serving as a first stage and WST2 serving as a second stage, off-axis alignment systems ALG1 and ALG2, serving as a first 5 and a second mark detection system, a control system for these components or assemblies, and the like. On wafer stages WST1 and WST2, substrates serving as wafers are to be mounted. In FIG. 1, a wafer W1 is mounted on wafer stage WST1, and a wafer W2 is mounted on wafer stage WST2.

10 [0029] As is disclosed in, for example, Kokai (Japanese Unexamined Patent Application Publication) No. 6-349701 (corresponding U.S. Patent No. 5,534,970) or the like, illumination system 10 is configured including a light source and an illuminance uniformity optical system, which 15 includes an optical integrator, and the like. Illumination system 10 also includes a beam splitter, a relay lens, a variable ND filter, a reticle blind, and the like (all of which are not shown). In illumination system 10, an illumination light (exposure light) IL illuminates a slit-shaped 20 illumination area set by the reticle blind on reticle R with a substantially uniform illuminance. In this case, for example, an ArF excimer laser beam (wavelength: 193 nm) is used as illumination light IL. Further, as the optical integrator, a fly-eye lens, a rod integrator (an internal reflection type integrator), a diffractive optical element 25 or the like can be used.

[0030] On reticle stage RST, reticle R on which a circuit pattern or the like is formed on its pattern surface

(the lower surface in FIG. 1) is fixed, for example, by vacuum chucking. Reticle stage RST is finely drivable or movable in within an XY plane perpendicular to the optical axis of illumination system 10 (coincides with an optical axis AX of 5 a projection optical system PL that will be described later) by a reticle stage drive section 11 (not shown in FIG. 1, refer to FIG. 5) that includes a linear motor or the like. Reticle stage RST is also drivable in a predetermined scanning direction (in this case, a Y-axis direction, which is the 10 direction orthogonal to the page surface in FIG. 1) at a designated scanning speed.

[0031] The position of reticle stage RST within the stage moving plane is constantly detected by a reticle laser interferometer (hereinafter referred to as 'reticle 15 interferometer') 116 via a movable mirror 15 at a resolution of, for example, around 0.5 to 1 nm. In actual, on reticle stage RST, a Y movable mirror that has a reflection surface orthogonal to the Y-axis direction and an X movable mirror that has a reflection surface orthogonal to an X-axis direction 20 are arranged, and corresponding to these movable mirrors, a reticle Y interferometer and a reticle X interferometer are arranged; however in FIG. 1, such details are representatively shown as movable mirror 15 and reticle interferometer 116. Incidentally, for example, the edge surface of reticle stage 25 RST may be polished in order to form a reflection surface (corresponds to the reflection surfaces of the X movable mirror and the Y movable mirror described above). Further, instead of the reflection surface that extends in the X-axis direction

used for detecting the position of reticle stage RST in the scanning direction (the Y-axis direction in this embodiment), at least one corner cubic mirror (such as a retroreflector) may be used. Of the interferometers reticle Y interferometer 5 and reticle X interferometer, one of them, such as reticle Y interferometer, is a dual-axis interferometer that has two measurement axes, and based on the measurement values of reticle Y interferometer, the rotation of reticle stage RST in a rotation direction (a θ_z direction) around a Z-axis can 10 be measured in addition to the Y position of reticle stage RST.

[0032] The measurement values of reticle interferometer 116 are sent to a main controller 20 (not shown in FIG. 1, refer to FIG. 5), and based on the measurement values 15 of reticle interferometer 116, main controller 20 computes the position of reticle stage RST in the X, Y, and θ_z directions and also controls the position (and velocity) of reticle stage RST by controlling reticle stage drive section 11 based on the computation results.

20 [0033] Above reticle R, reticle alignment detection systems RAa and RAb in pairs, each consisting of a TTR (Through The Reticle) alignment system that uses light of the exposure wavelength to observe a reticle mark on reticle R and a corresponding fiducial mark on a fiducial mark plate at the 25 same time via projection optical system PL, are arranged in the X-axis direction at a predetermined distance. As such reticle alignment detection systems RAa and RAb, a system having a structure similar to the one disclosed in, for example,

Kokai (Japanese Unexamined Patent Application Publication) No. 7-176468 (corresponding U.S. Patent No. 5,646,413) or the like is used.

[0034] Projection unit PU is arranged below reticle stage RST in FIG. 1. Projection unit PU is configured including a barrel 40, and projection optical system PL consisting of a plurality of optical elements held in a predetermined positional relation within barrel 40. As projection optical system PL, a dioptric system is used, consisting of a plurality of lenses (lens elements) that share an optical axis AX in the Z-axis direction. Projection optical system PL is, for example, a both-side telecentric dioptric system that has a predetermined projection magnification (such as one-quarter or one-fifth times) is used. Therefore, when illumination light IL from illumination system 10 illuminates the illumination area on reticle R, a reduced image of the circuit pattern within the illumination area of reticle R (a partial reduced image of the circuit pattern) is formed on the wafer whose surface is coated with a resist (a photosensitive agent) by illumination light IL that has passed through reticle R, via projection unit PU (projection optical system PL).

[0035] In exposure apparatus 100 of the embodiment, because exposure is performed applying the immersion method (to be described later), the numerical aperture NA substantially increases which makes the opening on the reticle side larger. Therefore, in a dioptric system consisting only of lenses, it becomes difficult to satisfy the Petzval

condition, which tends to lead to an increase in the size of the projection optical system. In order to prevent such an increase in the size of the projection optical system, a catadioptric system that includes mirrors and lenses may also 5 be used.

[0036] Further, in the embodiment, a liquid supply/drainage system 32 for locally supplying a liquid in the space between a lens 91 constituting projection optical system PL closest to the image plane side (the wafer side) 10 (hereinafter also referred to as a 'tip lens') and the wafer on wafer stage WST1 or WST2 (or between tip lens 91 and wafer stage WST1 or WST2). In FIG. 1, a nozzle constituting this liquid supply/drainage unit is representatively shown as liquid supply/drainage system 32. The arrangement or the like 15 of liquid supply/drainage system 32 will be described later in the description.

[0037] Wafer stage unit 50 is equipped with a base platform 12, wafer stages WST1 and WST2 arranged above the upper surface of base platform 12, an interferometer system 20 118 (refer to FIG. 5) serving as a position measuring unit that includes interferometers 16 and 18 for measuring the positions of wafer stages WST1 and WST2, and a wafer stage drive section 124 (refer to FIG. 5) for driving wafer stages WST1 and WST2.

25 [0038] On the bottom surface of wafer stages WST1 and WST2, non-contact bearings (not shown) such as, for example, vacuum preload air bearings (hereinafter referred to as 'air pads') are arranged in a plurality of areas, and by the static

pressure of the pressurized air blowing out from the air pads toward the upper surface of base platform 12, wafer stages WST1 and WST2 are supported by levitation in a non-contact manner above the upper surface of base platform 12 via a 5 clearance of around several μ m. Further, wafer stages WST1 and WST2 are configured drivable or movable in a two-dimensional direction, individually in the X-axis direction (the lateral direction of the page surface in FIG. 1) and the Y-axis direction (the orthogonal direction of the 10 page surface in FIG. 1), by wafer stage drive section 124.

[0039] On base platform 12, as is shown in the planar view in FIG. 2, X-axis linear guides 86 and 87 in pairs, extending in the X-axis direction, are arranged at a predetermined distance in the Y-axis direction. X-axis 15 linear guides 86 and 87 are each configured, for example, of a magnetic pole unit that incorporates a permanent magnet group consisting of a plurality of sets of an N-pole magnet and an S-pole magnet alternately arranged along the X-axis direction at a predetermined distance. Above X-axis linear guides 86 and 87, two sliders each, sliders 82, 84 and sliders 83, 85 20 are arranged in a state enclosing the corresponding X-axis linear guides 86 and 87 from above in a non-contact manner. More specifically, the four sliders in total, 82, 84, 83, and 25 85 have a cross-sectional shape resembling the letter U so as to enclose the corresponding X-axis linear guides 86 and 87 from above and from the side, and the sliders are supported by levitation with respect to the corresponding X-axis linear guides 86 and 87, via the air pads (not shown) via a clearance

of (e.g.) around several μ m. Sliders 82, 84, 83, and 85 are each configured by an armature unit that incorporates a plurality of armature coils arranged along the X-axis direction at a predetermined distance. More specifically, in 5 the embodiment, sliders 82 and 84 consisting of armature units and X-axis linear guide 86 consisting of the magnetic pole unit constitute moving magnet type X-axis linear motors. Similarly, sliders 83 and 85 and X-axis linear guide 87 constitute moving magnet type X-axis linear motors. In the 10 description below, the four X-axis linear motors will each be appropriately referred to as X-axis linear motor 82, X-axis linear motor 84, X-axis linear motor 83, and X-axis linear motor 85, using the same reference numerals as the sliders 82, 84, 83, and 85 configuring each of the movers.

15 [0040] Of the four X-axis linear motors referred to above, the sliders that configure the two X-axis linear motors, 82 and 83, are fixed to both ends in the longitudinal direction of a Y-axis linear guide 80 extending in the Y-axis direction. Further, the sliders that configure the remaining two X-axis 20 linear motors, 84 and 85, are fixed to both ends of a Y-axis linear guide 81 extending in the Y-axis direction. Accordingly, Y-axis linear guides 80 and 81 are each driven along the X-axis by the pair of X-axis linear motors 82 and 83 and by the pair of X-axis linear motors 84 and 85, 25 respectively.

[0041] Y-axis linear guides 80 and 81 are each configured, for example, by an armature unit that incorporates armature coils arranged along the Y-axis direction at a

predetermined distance.

[0042] One of the Y-axis linear guides, Y-axis linear guide 81, is arranged in an inserted state in an opening formed in wafer stage WST1. Inside the opening referred to above of 5 wafer stage WST1, for example, a magnetic pole unit that has a permanent magnet group consisting of a plurality of sets of an N-pole magnet and an S-pole magnet alternately arranged along the Y-axis direction at a predetermined distance is arranged. And, the magnetic pole unit and Y-axis linear guide 10 81 constitute a moving magnet type Y-axis linear motor that drives wafer stage WST1 in the Y-axis direction. Similarly, the other Y-axis linear guide, Y-axis linear guide 80, is arranged in an inserted state in an opening formed in wafer stage WST2. Inside the opening referred to above of wafer 15 stage WST2, for example, a magnetic pole unit similar to the one arranged in wafer stage WST1 side is arranged. And, the magnetic pole unit and Y-axis linear guide 80 constitute a moving magnet type Y-axis linear motor that drives wafer stage WST2 in the Y-axis direction. In the description below, the 20 Y-axis linear motors will each be appropriately referred to as Y-axis linear motor 81 and Y-axis linear motor 80, using the same reference numerals as the linear guides 81 and 80 configuring each of the stators.

[0043] In the embodiment, wafer stage drive section 25 124 shown in FIG. 5 is configured by X-axis linear motors 82 to 85 and Y-axis linear motors 80 and 81. Each of the linear motors described above that configure wafer stage drive section 124 operate under the control of main controller 20

shown in FIG. 5.

[0044] By slightly changing the thrust generated by the pair of X-linear motors 84 and 85 (or 82 and 83), yawing control of wafer stage WST1 (or WST2) becomes possible.

5 [0045] In the embodiment, wafer stages WST1 and WST2 are each shown as a monolithic stage. In actual, however, wafer stages WST1 and WST2 are each equipped with a stage main body driven by Y-axis linear motors 81 and 80, and a wafer table mounted on the wafer stage main body via a Z-leveling drive 10 mechanism (such as a voice coil motor or the like) that can be finely driven or moved relatively in the Z-axis direction and in the rotational directions around the X-axis (θ_x direction) and the Y-axis (θ_y direction).

[0046] On wafer stage WST1 (or to be more precise, 15 on the wafer table), as is shown in FIG. 1, a wafer holder H1 that holds wafer W1 by vacuum suction or the like is arranged. As it can be seen from the perspective view in FIG. 3, wafer holder H1 has a roughly square shape main body section 70 in a planar view (when viewed from above), and four auxiliary 20 plates 72a to 72d arranged in the periphery of the area where wafer W1 is to be mounted so that they overlap main body section 70 from above. The surfaces of such auxiliary plates 72a to 72d are arranged so that they are substantially the same height as the surface of wafer W1. Incidentally, auxiliary plates 25 72a to 72d may consist of a single member. Further, it is desirable to keep the upper surfaces of movable mirrors 17X and 17Y at substantially the same height (flush) as wafer W1.

[0047] As is shown in FIG. 3, a gap D exists between

each of the auxiliary plates 72a to 72d and wafer W1. The size of the gap is set from 0.1 mm to 1 mm and under. In addition, a notch (a V-shaped cut) is formed in a part of wafer W; however, the notch is omitted in the drawings since the size of the 5 notch is also around 1 mm.

[0048] Further, a circular opening is formed in a part of auxiliary plate 72a, and a fiducial mark plate FM1 is embedded into the opening. The surface of fiducial mark plate FM1 is to be on the same plane as auxiliary plate 72a. On the 10 surface of fiducial mark plate FM1, at least a first fiducial mark in pairs for reticle alignment, a second fiducial mark detected by alignment system ALG1 in the manner described later (none of which are shown), and the like are formed.

[0049] On the upper surface of wafer stage WST1, an 15 X movable mirror 17X that has a reflection surface orthogonal to the X-axis on one end in the X-axis direction (the +X side end) is arranged extending in the Y-axis direction, and a Y movable mirror 17Y that has a reflection surface orthogonal to the Y-axis on one end in the Y-axis direction (the +Y side 20 end) is arranged extending in the X-axis direction. As is shown in FIG. 2, interferometer beams (measurement beams) from the interferometers that configure interferometer system 118 (to be described later, refer to FIG. 5) are incident on each 25 reflection surface of movable mirrors 17X and 17Y, and by each of the interferometers receiving the reflection beams, displacement from the reference position (normally, a fixed mirror is arranged on the side surface of projection unit PU or on the side surface of alignment system ALG1, which is to

be the reference plane) of the reflection surface of each movable mirror is measured. Accordingly, the two-dimensional position of wafer stage WST1 is measured.

[0050] On wafer stage WST2 (or to be more precise, 5 on the wafer table), a wafer holder H2 that holds wafer W2 by vacuum suction or the like is arranged, as is shown in FIG. 1. Wafer holder H2 has an arrangement similar to wafer holder H1 previously described. Accordingly, in the circular opening formed in a part of an auxiliary plate configuring 10 wafer holder H2, a fiducial mark plate FM2 is embedded (not shown in FIG. 1, refer to FIG. 2).

[0051] Further, on the upper surface of wafer stage WST2, an X movable mirror 117X that has a reflection surface orthogonal to the X-axis on one end in the X-axis direction 15 (the -X side end) is arranged extending in the Y-axis direction, and a Y movable mirror 117Y that has a reflection surface orthogonal to the Y-axis on one end in the Y-axis direction (the +Y side end) is arranged extending in the X-axis direction. As is shown in FIG. 2, interferometer beams (measurement beams) 20 from the interferometers that configure interferometer system 118 (to be described later, refer to FIG. 5) are incident on each reflection surface of movable mirrors 117X and 117Y, and by each of the interferometers receiving the reflection beams, displacement from the reference position of the reflection 25 surface of each movable mirror is measured. Accordingly, the two-dimensional position of wafer stage WST2 is measured.

[0052] Incidentally, the end surfaces of wafer stages WST1 and WST2 can be mirror-polished so as to make reflection

surfaces (corresponding to the reflection surfaces of movable mirrors 17X, 17Y, 117X, and 117Y previously described).

[0053] Further, on the surface on the side of wafer stages WST1 and WST2 that face each other, e.g. the -X side 5 surface of wafer stage WST1, a seal member 93 is applied covering the entire surface as is shown in FIG. 10. As such seal member 93, for example, an elastic seal member made of fluorine-contained rubber or the like is used.

[0054] Instead of applying seal member 93 to the -X 10 side surface of wafer stage WST1, seal member 93 can be applied to the +X side surface of wafer stage WST2, or seal member 93 can be applied to the -X side surface of wafer stage WST1 and the +X side surface of wafer stage WST2.

[0055] Referring back to FIG. 1, on both sides of 15 projection unit PU on the +X side and the -X side at positions equally apart, off-axis alignment systems (hereinafter simply referred to as 'alignment systems') ALG1 and ALG2 referred to earlier are disposed. In actual, alignment systems ALG1 and ALG2 are attached to a holding member that holds projection 20 unit PU. As alignment systems ALG1 and ALG2, for example, a sensor of an FIA (Field Image Alignment) system based on an image-processing method is used. This sensor irradiates a broadband detection beam that does not expose the resist on the wafer on a target mark, picks up the images of the target 25 mark formed on the photodetection surface by the reflection light from the target mark and an index (not shown; an index pattern on an index plate arranged inside alignment systems ALG1 and ALG2) with a pick-up device (such as a CCD), and

outputs the imaging signals. Incidentally, alignment systems ALG1 and ALG2 are not limited to the FIA system, and it is a matter of course that an alignment sensor that irradiates a coherent detection light on a target mark and detects the 5 scattered light or diffracted light generated from the target mark, or a sensor that detects two diffracted lights (e.g. diffracted lights of the same order, or diffracted lights diffracting in the same direction) generated from the target mark by making them interfere with each other can be used 10 independently, or appropriately combined.

[0056] In the embodiment, alignment system ALG1 is used for measuring the position of alignment marks formed on wafer W1, fiducial marks formed on fiducial mark plate FM1, and the like. Further, alignment system ALG2 is used for 15 measuring the position of alignment marks formed on wafer W2, fiducial marks formed on fiducial mark plate FM2, and the like.

[0057] Information from these alignment systems ALG1 and ALG2 is to be supplied to main controller 20, as is shown in FIG. 5.

20 [0058] Next, the arrangement and the like of interferometer system 118 will be described, referring to FIG. 2. As is shown in FIG. 2, interferometer system 118 has three Y-axis interferometers, 46, 48, and 44 whose measurement axes are BI2Y, BI3Y, and BI1Y. The measurement axes are parallel 25 to the Y-axis, and respectively pass through the detection center of projection optical system PL (optical axis AX), the detection center of alignment system ALG1, and the detection center of alignment system ALG2. Interferometer system 118

also has two X-axis interferometers, 16 and 18 whose measurement axes are BI1X and BI2X. These measurement axes are parallel to the X-axis, and respectively join the detection center of projection optical system PL (optical axis AX) and 5 the detection center of alignment system ALG1, and the detection center of projection optical system PL (optical axis AX) and the detection center of alignment system ALG2.

[0059] In this case, when wafer stage WST1 is in the area (a first area) in the vicinity of the position (a first 10 position) directly under the optical axis of projection optical system PL and exposure of the wafer on wafer stage WST1 is to be performed, the position of wafer stage WST1 is controlled by X-axis interferometer 18 and Y-axis interferometer 46. In the description below, the coordinate 15 system set by the measurement axes of X-axis interferometer 18 and Y-axis interferometer 46 will be referred to as a first exposure coordinate system.

[0060] Further, when wafer stage WST2 is in the first area of projection optical system PL and exposure of the wafer 20 on wafer stage WST2 is to be performed, the position of wafer stage WST1 is controlled by X-axis interferometer 16 and Y-axis interferometer 46. In the description below, the coordinate system set by the measurement axes of X-axis interferometer 16 and Y-axis interferometer 46 will be referred to as a second 25 exposure coordinate system.

[0061] Further, when wafer stage WST1 is in the area (a second area) in the vicinity of the position directly under the detection center of alignment system ALG1 and detection

of alignment marks formed on the wafer on wafer stage WST1 such as wafer alignment (to be described later) is to be performed, the position of wafer stage WST1 is controlled by X-axis interferometer 18 and Y-axis interferometer 48. In the 5 description below, the coordinate system set by the measurement axes of X-axis interferometer 18 and Y-axis interferometer 48 will be referred to as a first alignment coordinate system.

[0062] Further, when wafer stage WST2 is in the area 10 (a third area) in the vicinity of the position directly under the detection center of alignment system ALG2 and detection of alignment marks formed on the wafer on wafer stage WST2 such as wafer alignment (to be described later) is to be performed, the position of wafer stage WST2 is controlled by 15 X-axis interferometer 16 and Y-axis interferometer 44. In the description below, the coordinate system set by the measurement axes of X-axis interferometer 16 and Y-axis interferometer 44 will be referred to as a second alignment coordinate system.

20 [0063] As is obvious from the description above, in the embodiment, the interferometer beams from X-axis interferometers 18 and 16 constantly irradiate movable mirrors 17X and 117X of wafer stages WST1 and WST2, respectively, in the entire moving range of wafer stages WST1 25 and WST2. Accordingly, for the X-axis direction, the position of wafer stages WST1 and WST2 is controlled by X-axis interferometers 18 and 16 in any case, such as when exposure is performed using projection optical system PL and also when

alignment systems ALG1 and ALG2 are used. Such X-axis interferometers 18 and 16 are both multi-axis interferometers that have a plurality of optical axes, and the output values of each optical axis can be measured independently.

5 Accordingly, with these X interferometers 18 and 16, other than measuring the position of wafer stages WST1 and WST2 in the X-axis direction, the rotation amount around the Y-axis (rolling amount) and the rotation amount around the Z-axis (yawing amount) can also be measured.

10 [0064] Further, Y-axis interferometers 44, 46, and 48 are dual-axis interferometers, for example, each having two optical axes that are separate, and the output values of each optical axis can be measured independently. Accordingly, with these Y-axis interferometers 44, 46, and 48, other than
15 measuring the position of wafer stages WST1 and WST2 in the Y-axis direction, the rotation amount around the X-axis (pitching amount) can also be measured.

[0065] Further, the multi-axis interferometers described above may detect positional information related to
20 the optical axis direction (the Z-axis direction) of projection optical system PL, by irradiating laser beams on a reflection surface arranged on the frame on which projection optical system PL is mounted (not shown), via reflection surfaces arranged on wafer stages WST1 and WST2 at an
25 inclination of 45°.

[0066] Next, details on liquid supply/drainage system 32 will be described, referring to FIG. 4. Liquid supply/drainage system 32 is equipped with a liquid supply

unit 5, a liquid recovery unit 6, supply pipes 21, 22, 27, and 28 connecting to liquid supply unit 5 and recovery pipes 23, 24, 29, 30 connecting to liquid recovery unit 6 and the like.

5 [0067] Liquid supply unit 5 is configured to include a liquid tank, a compression pump, a temperature control unit, a plurality of valves for controlling the supply/stop of the liquid to supply pipes 21, 22, 27, and 28, and the like. As the valves referred to above, flow control valves are
10 preferably used so that not only the supply/stop of the liquid but also the flow rate can be adjusted. The temperature control unit adjusts the temperature of the liquid within the liquid tank so that the temperature of the liquid is about the same level as the temperature within the chamber (not
15 shown) where the exposure apparatus main body constituted by projection unit PU and the like are housed.

[0068] One end of supply pipe 21 connects to liquid supply unit 5. The other end branches into three sections where on each end, supply nozzles 21a, 21b, and 21c consisting
20 of a tapered nozzle are respectively formed. The tip of these supply nozzles 21a, 21b, and 21c are located in the vicinity of tip lens 91 (refer to FIG. 1) previously described, and are arranged in the X-axis direction at a predetermined distance and also close to the +Y side of an exposure area
25 IA (an area on the image plane conjugate with the illumination area on the slit previously described). The supply nozzles are arranged symmetrically, with supply nozzle 21a in the center and supply nozzles 21b and 21c on both sides.

[0069] One end of supply pipe 22 connects to liquid supply unit 5. The other end branches into three sections where on each end, supply nozzles 22a, 22b, and 22c consisting of a tapered nozzle are respectively formed. The tip of these 5 supply nozzles 22a, 22b, and 22c are located in the vicinity of tip lens 91, and are arranged in the X-axis direction at a predetermined distance and also close to the -Y side of exposure area IA. In this case, supply nozzles 22a, 22b, and 22c are arranged facing supply nozzles 21a, 21b, and 21c, with 10 exposure area IA in between.

[0070] One end of supply pipe 27 connects to liquid supply unit 5. The other end has a supply nozzle 27a consisting of a tapered nozzle formed. The tip of supply nozzle 27a is located in the vicinity of tip lens 91, and is arranged close 15 to the -X side of exposure area IA.

[0071] One end of supply pipe 28 connects to liquid supply unit 5. The other end has a supply nozzle 28a consisting of a tapered nozzle formed. The tip of supply nozzle 28a is located in the vicinity of tip lens 91, and is arranged close 20 to the +X side of exposure area IA and also faces supply nozzle 27a, with exposure area IA in between.

[0072] Liquid recovery unit 6 is configured to include a liquid tank and a suction pump, and a plurality of valves for controlling the recovery/stop of the liquid via 25 recovery pipes 23, 24, 29, and 30, and the like. As the valves, flow control valves are preferably used corresponding to the valves used in the liquid supply unit 5.

[0073] One end of recovery pipe 23 connects to liquid

recovery unit 6. The other end branches into two sections where on each end, recovery nozzles 23a and 23b consisting of a widened nozzle are respectively formed. In this case, recovery nozzles 23a and 23b are arranged alternately in
5 between supply nozzles 22a to 22c. The tip of recovery nozzles 23a and 23b and the tip of supply nozzles 22a, 22b, and 22c are arranged substantially collinear on a line parallel to the X-axis.

[0074] One end of recovery pipe 24 connects to liquid
10 recovery unit 6. The other end branches into two sections where on each end, recovery nozzles 24a and 24b consisting of a widened nozzle are respectively formed. In this case, recovery nozzles 24a and 24b are arranged alternately in between supply nozzles 21a to 21c and also face recovery
15 nozzles 23a and 23b, with exposure area IA in between. The tip of recovery nozzles 24a and 24b and the tip of supply nozzles 21a, 21b, and 21c are arranged substantially collinear on a line parallel to the X-axis.

[0075] One end of recovery pipe 29 connects to liquid
20 recovery unit 6. The other end branches into two sections where on each end, recovery nozzles 29a and 29b consisting of a widened nozzle are respectively formed. Recovery nozzles 29a and 29b are arranged with supply nozzle 28a in between. The tip of recovery nozzles 29a and 29b and the tip of supply
25 nozzle 28a are arranged substantially collinear on a line parallel to the Y-axis.

[0076] One end of recovery pipe 30 connects to liquid recovery unit 6. The other end branches into two sections

where on each end, recovery nozzles 30a and 30b consisting of a widened nozzle are respectively formed (arranged). Recovery nozzles 30a and 30b are arranged with supply nozzle 27a in between, and also face recovery nozzles 29a and 29b, 5 with exposure area IA in between. The tip of recovery nozzles 30a and 30b and the tip of supply nozzle 27a are arranged substantially collinear on a line parallel to the Y-axis.

[0077] In the embodiment, as the liquid, ultra pure water (hereinafter, it will simply be referred to as 'water' 10 besides the case when specifying is necessary) that transmits the ArF excimer laser beam (light with a wavelength of 193 nm) is to be used. Ultra pure water can be obtained in large quantities at a semiconductor manufacturing plant or the like, and it also has an advantage of having no adverse effect on 15 the photoresist on the wafer or to the optical lenses. Further, ultra pure water has no adverse effect on the environment as well as an extremely low concentration of impurities, therefore, cleaning action on the surface of the wafer and the surface of tip lens 91 can be anticipated.

20 [0078] Refractive index n of the water is said to be around 1.44. In the water the wavelength of illumination light IL is $193 \text{ nm} \times 1/n$, shorted to around 134 nm.

[0079] Liquid supply unit 5 and liquid recovery unit 6 both have a controller, and the controllers operate under 25 the control of main controller 20 (refer to FIG. 5). For example, when wafer W1 (or wafer W2) is moved in a direction shown by a solid arrow A in FIG. 4 (-Y direction), according to instructions from main controller 20, the controller of

liquid supply unit 5 opens the valve connected to supply pipe 21 to a predetermined degree and completely closes the other valves so as to supply the water in the space between tip lens 91 and wafer W1 (or W2) toward the -Y direction via supply nozzles 21a to 21c arranged in supply pipe 21. Further, when the water is supplied, according to instructions from main controller 20, the controller of liquid recovery unit 6 opens the valve connected to recovery pipe 23 to a predetermined degree and completely closes the other valves so that the water is recovered into liquid recovery unit 6 from the space between tip lens 91 and wafer W1 (or W2) via recovery nozzles 23a and 23b. During the supply and recovery operations, main controller 20 gives orders to liquid supply unit 5 and liquid recovery unit 6 so that the amount of water supplied to the space between tip lens 91 and wafer W1 (or W2) toward the -Y direction from supply nozzles 21a to 21c constantly equals the amount of water recovered via recovery nozzles 23a and 23b. Accordingly, a constant amount of water Lq (refer to FIG. 1) is held or retained in the space between tip lens 91 and wafer W1 (or W2). In this case, water Lq held in the space between tip lens 91 and wafer W1 (or W2) is constantly replaced.

[0080] Further, when wafer W1 (or wafer W2) is moved in a direction shown by a dotted arrow A' in FIG. 4 (+Y direction), according to instructions from main controller 20, the controller of liquid supply unit 5 opens the valve connected to supply pipe 22 to a predetermined degree and completely closes the other valves so as to supply the water in the space between tip lens 91 and wafer W1 (or W2) toward

the +Y direction via supply nozzles 22a to 22c arranged in supply pipe 22. Further, when the water is supplied, according to instructions from main controller 20, the controller of liquid recovery unit 6 opens the valve connected 5 to recovery pipe 24 to a predetermined degree and completely closes the other valves so that the water is recovered into liquid recovery unit 6 from the space between tip lens 91 and wafer W1 (or W2) via recovery nozzles 24a and 24b. During the supply and recovery operations, main controller 20 gives 10 orders to liquid supply unit 5 and liquid recovery unit 6 so that the amount of water supplied to the space between tip lens 91 and wafer W1 (or W2) toward the +Y direction from supply nozzles 22a to 22c constantly equals the amount of water recovered via recovery nozzles 24a and 24b. Accordingly, a 15 constant amount of water Lq (refer to FIG. 1) is held in the space between tip lens 91 and wafer W1 (or W2). In this case, water Lq held in the space between tip lens 91 and wafer W1 (or W2) is constantly replaced.

[0081] As is described above, in the embodiment, a 20 group of supply nozzles and a group of recovery nozzles that are grouped together is arranged on both one side and the other side of the Y-axis direction with exposure area IA in between. Therefore, in the case the wafer is moved in either the +Y direction or in the -Y direction, the space between wafer W1 25 (or W2) and tip lens 91 continues to be filled stably with the water. That is, in both the so-called plus-scan and the minus scan, the water can be stably held in the space between the wafer and tip lens 91.

[0082] Further, because the water flows over wafer W1 (or W2), in the case foreign particles (including scattered particles from the resist) adhere on wafer W1 (or wafer W2), the water can remove such foreign particles. Further, because 5 liquid supply unit 5 supplies water whose temperature is adjusted to a predetermined temperature and the water is constantly replaced, even if illumination light IL is irradiated on wafer W1 (or W2) on exposure, heat exchange is performed between the wafer and the water flowing over the 10 wafer, which can suppress temperature increase of the wafer surface. Further, in the embodiment, because the water flows in the same direction as the moving direction of the wafer, the liquid that has absorbed the foreign particles or heat can be recovered without the liquid staying in the exposure 15 area directly under the tip lens.

[0083] Further, when wafer W1 (or wafer W2) is moved in a direction shown by a solid arrow B in FIG. 4 (+X direction), according to instructions from main controller 20, the controller of liquid supply unit 5 opens the valve connected 20 to supply pipe 27 to a predetermined degree and completely closes the other valves so as to supply the water in the space between tip lens 91 and wafer W1 (or W2) toward the +X direction via supply nozzle 27a arranged in supply pipe 27. Further, when the water is supplied, according to instructions from 25 main controller 20, the controller of liquid recovery unit 6 opens the valve connected to recovery pipe 29 to a predetermined degree and completely closes the other valves so that the water is recovered into liquid recovery unit 6

from the space between tip lens 91 and wafer W1 (or W2) via recovery nozzles 29a and 29b. During the supply and recovery operations, main controller 20 gives orders to liquid supply unit 5 and liquid recovery unit 6 so that the amount of water supplied to the space between tip lens 91 and wafer W1 (or W2) from supply nozzle 27a constantly equals the amount of water recovered via recovery nozzles 29a and 29b. Accordingly, a constant amount of water L_q (refer to FIG. 1) is held in the space between tip lens 91 and wafer W1 (or W2). In this case, water L_q held in the space between tip lens 91 and wafer W1 (or W2) is constantly replaced.

[0084] Further, when wafer W1 (or wafer W2) is moved in a direction shown by a dotted arrow B' in FIG. 4 (-X direction), according to instructions from main controller 20, the controller of liquid supply unit 5 opens the valve connected to supply pipe 28 to a predetermined degree and completely closes the other valves so as to supply the water in the space between tip lens 91 and wafer W1 (or W2) toward the -X direction via supply nozzle 28a arranged in supply pipe 28. Further, when the water is supplied, according to instructions from main controller 20, the controller of liquid recovery unit 6 opens the valve connected to recovery pipe 30 to a predetermined degree and completely closes the other valves so that the water is recovered into liquid recovery unit 6 from the space between tip lens 91 and wafer W1 (or W2) via recovery nozzles 30a and 30b. During the supply and recovery operations, main controller 20 gives orders to liquid supply unit 5 and liquid recovery unit 6 so that the amount

of water supplied to the space between tip lens 91 and wafer W1 (or W2) toward the +Y direction from supply nozzle 28a constantly equals the amount of water recovered via recovery nozzles 30a and 30b. Accordingly, a constant amount of water 5 Lq (refer to FIG. 1) is held in the space between tip lens 91 and wafer W1 (or W2). In this case, water Lq held in the space between tip lens 91 and wafer W1 (or W2) is constantly replaced.

[0085] In the manner described above, as in the case 10 of moving wafer W1 (or W2) in the Y-axis direction, in the case of moving the wafer in either the +X direction or the -X direction, the space between the wafer and tip lens 91 continues to be filled stably with the water. Accordingly, during the so-called stepping operation between shots, the 15 water can be continuously held in the space between the wafer and tip lens 91.

[0086] In the description above, the case has been described in which the water is held in the space between the wafer and the tip lens. However, as is previously described, 20 because the wafer surface and the surface of wafer holders H1 and H2 are substantially flush, even in the case wafer holder H1 (or H2) is located at a position corresponding to exposure area IA directly under projection unit PU, the water is held in the space between tip lens 91 and wafer holder H1 (or H2), 25 or in other words, the auxiliary plates previously described, as in the description above. Further, during the stepping operation, in the case the water can be held in the space between the wafer and tip lens 91, the water supply and recovery

can be stopped.

[0087] In addition to the nozzles that supply and recover the water from the X-axis direction or the Y-axis direction, for example, nozzles that supply and recover the
5 water from an oblique direction can also be arranged.

[0088] In exposure apparatus 100 of the embodiment, further in the holding member that holds projection unit PU (not shown), a multiple point focal position detection system based on an oblique method constituted by an irradiation system
10 90a (not shown in FIG. 1, refer to FIG. 5) and a photodetection system 90b (not shown in FIG. 1, refer to FIG. 5), similar to the one disclosed in, for example, Kokai (Japanese Patent Unexamined Application Publication) No. 6-283403
15 (corresponding U.S. Patent No. 5,448,332), is arranged.
Irradiation system 90a has a light source whose on/off is controlled by main controller 20 in FIG. 5, and emits imaging beams toward the imaging plane of projection optical system PL so as to form a large number of pinholes or slit images. The emitted imaging beams are irradiated on the wafer surface
20 from an oblique direction against optical axis AX via a prism (not shown, a part of the optical system in irradiation system 90a) arranged on the barrel of projection unit PU. Meanwhile, the beams of the imaging beams reflected off the wafer surface are reflected by another prism (not shown, a part of the optical system in photodetection system 90b) arranged on the barrel
25 of projection unit PU, and are received by a photodetection element in photodetection system 90b.

[0089] Defocus signals, which are an output of

photodetection system 90b of focal position detection system (90a, 90b), are sent to main controller 20. On scanning exposure (to be described later) or the like, main controller 20 computes the Z position of the wafer surface and the θ_x and θ_y rotations based on defocus signals such as the S-curve signal from photodetection system 90b, and controls the movement of wafer stages WST1 and WST2 in the Z-axis direction and the inclination in a two-dimensional direction (that is, rotation in the θ_x and θ_y direction) via wafer stage drive section 124 so that the difference between the Z position of the wafer surface and the θ_x and θ_y rotations that have been calculated and their target values become zero, or in other words, defocus equals zero. And, by such control, main controller 20 performs auto-focusing (automatic focusing) and auto-leveling in which the imaging plane of projection optical system PL and the surface of the wafer are made to substantially coincide with each other within the irradiation area (in an image-forming relation with the illumination area described earlier) of illumination light IL.

[0090] FIG. 5 shows a main arrangement of a control system of exposure apparatus 100 of the embodiment. The control system is mainly composed of main controller 20, which is made up of a microcomputer (or a workstation) or the like having overall control over the entire apparatus.

[0091] Next, the operation of each section on exposure in exposure apparatus 100 of the embodiment will be described. In the following description, as is shown in FIG. 2, the case when exposure is performed on the wafer stage WST1

side will be described.

[0092] On starting the exposure operation, main controller 20 moves wafer stage WST1 to a scanning starting position (acceleration starting position) for exposure of the 5 first shot area on wafer W by controlling X-axis linear motors 84 and 85 and Y-axis linear motor 81 while monitoring the measurement values of interferometers 18 and 46, based on the results of wafer alignment performed in advance such as, for example, Enhanced Global Alignment (EGA). In this exposure 10 sequence, the position of wafer stage WST1 is controlled on the first exposure coordinate system.

[0093] Next, main controller 20 begins the relative scanning of reticle R (reticle stage RST) and wafer W1 (wafer stage WST1) in the Y-axis direction. On this relative 15 scanning, main controller 20 controls both reticle stage drive section 11 and Y-axis linear motor 81 (and X-axis linear motors 84 and 85), while monitoring the measurement values of interferometers 18 and 46 and reticle interferometer 116 previously described.

20 [0094] Then, when both stages RST and WST1 reach their target scanning speed, main controller 20 gives instructions to the light source (the ArF excimer laser unit, not shown) to start pulse emission. And, when both stages, RST and WST, reach a constant speed synchronous state, illumination light 25 IL (ultraviolet pulse light) from illumination system 10 begins to illuminate the pattern area of reticle R, and scanning exposure begins. Pulse emission of the light source starts prior to the beginning of the scanning exposure as is

described above, however, main controller 20 moves predetermined blades of the movable reticle blind (not shown) within illumination system 10 synchronously with reticle stage RST, which prevents exposure from being performed on unnecessary areas of wafer W1 before the scanning exposure has been started.

[0095] Then, different areas in the pattern area of reticle R are sequentially illuminated by illumination light IL, and when the entire pattern area has been illuminated, scanning exposure of the first shot area of wafer W1 is completed. By this operation, the pattern of reticle R is reduced and transferred onto the first shot area via projection optical system PL.

[0096] In this case, after the exposure has been completed, main controller 20 continues to move the movable reticle blind (not shown) within illumination system 10 synchronously with reticle stage RST, which prevents unnecessary exposure of wafer W1.

[0097] When the scanning exposure of the first shot area has been completed in the manner described above, main controller 20 steps wafer stage WST1 via X-axis linear motors 84 and 85 and Y-axis linear motor 81 in the X-axis and Y-axis directions, and wafer stage WST1 is moved to the acceleration starting position (scanning starting position) for exposing the second shot area. During this stepping operation between shots, main controller 20 measures the positional displacement in the X, Y, and θz directions real-time based on the measurement values of interferometers 18 and 46. Then,

based on the measurement results, main controller 20 controls the position of wafer stage WST1 so that the XY positional displacement of wafer stage WST1 moves into a predetermined state. Further, based on the displacement information of 5 wafer stage WST1 in the θz direction, main controller 20 controls the rotation of at least either the reticle stage RST (reticle fine movement stage) or wafer stage WST1 so as to compensate the rotational displacement error on the wafer side.

10 [0098] Then, when the stepping operation between shots has been completed, main controller 20 controls the operation of each section as in the description above, and scanning exposure as in the description above is performed on the second shot area of wafer W1.

15 [0099] In this manner, the scanning exposure of the shot area of wafer W1 and the stepping operation for exposing the next shot are repeatedly performed, and the circuit pattern of reticle R is sequentially transferred onto all the shot areas subject to exposure on wafer W1.

20 [0100] Incidentally, during the exposure operation by the stepping-and-scan method to wafer W1 described above, it is a matter of course that main controller 20 performs the open/close operation of each valve in liquid supply unit 5 and liquid recovery unit 6 of liquid supply/drainage system 25 32 according to the moving direction of wafer W1 in a similar manner as is previously described. Accordingly, during the exposure operation by the stepping-and-scan method to wafer W1 described above, the state where a constant amount of water

is held stably in the space between tip lens 91 and wafer W1 is maintained.

[0101] Next, details on a parallel processing operation using the two wafer stages WST1 and WST2 will be 5 described, referring to FIG. 2 and to FIGS. 6 to 9. During the operation below, main controller 20 performs the open/close operation of each valve in liquid supply unit 5 and liquid recovery unit 6 of liquid supply/drainage system 32 according to the moving direction of the wafer stages 10 positioned at the first area directly under projection unit PU as is previously described, and the space directly under tip lens 91 of projection optical system PL is constantly filled with the water. However, in the description below, for the sake of simplicity, the description related to the control 15 of liquid supply unit 5 and liquid recovery unit 6 will be omitted.

[0102] FIG. 2 shows a state where exposure of wafer W1 on wafer stage WST1 is performed by the step-and-scan method in the manner previously described, while on the wafer stage 20 WST2 side, wafer alignment of wafer W2 positioned at the third area under alignment system ALG2 is being performed in parallel with the exposure.

[0103] While exposure of wafer W1 is performed by the step-and-scan method in the manner described above, the 25 following operation is being performed on the wafer stage WST2 side.

[0104] More specifically, prior to the wafer alignment referred to above, at a left-hand side loading

position, wafer exchange is performed between a wafer carrier mechanism (not shown) and wafer stage WST2. In this case, the left-hand side loading position is to be determined at a position directly under alignment system ALG2 where fiducial mark plate FM2 is positioned. In this case, at the left-hand side loading position, main controller 20 resets Y-axis interferometer 44 before alignment system ALG2 detects the second fiducial marks formed on fiducial mark plate FM2.

[0105] On the detection of the second fiducial marks referred to above, main controller 20 picks up the images of the second fiducial marks using alignment system ALG2, and performs a predetermined processing on the imaging signals, and by analyzing the signals that have been processed, main controller 20 detects the position of the second fiducial marks with the index center of alignment system ALG2 serving as a reference. Further, based on the detection results of the position of the second fiducial marks and the measurement results of interferometers 16 and 44 on the detection, main controller 20 computes the position coordinates of the second fiducial marks on the second alignment coordinate system.

[0106] Next, by detecting positional information (positional information with respect to the detection center of alignment system ALG2) of alignment marks (sample marks) arranged in a specific plurality of shot areas (sample shot areas) on wafer W2 using alignment system ALG2 while controlling the position of wafer stage WST2 on the second alignment coordinate system referred to earlier, main controller 20 obtains the positional information of the sample

marks on the second alignment coordinate system. Then, based on the detection results and the design position coordinates of the specific shot areas, main controller 20 executes statistical calculation such as the one disclosed in, for example, Kokai (Japanese Patent Unexamined Application Publication) No. 61-22249 (corresponding U.S. Patent No. 4,780,617), and computes or calculates the position coordinates of the plurality of shot areas on wafer W2 on the second alignment coordinate system. That is, in the manner described above, EGA (Enhanced Global Alignment) is performed. And then, by subtracting the position coordinates of the second fiducial marks described above from the position coordinates of the plurality of shot areas on wafer W2 on the second alignment coordinate system, main controller 20 converts the position coordinates of the plurality of shot areas into position coordinates using the position of the second fiducial marks as its origin.

[0107] Normally, in the exposure sequence and the wafer alignment/exchange sequence performed in parallel on the two stages, wafer stages WST1 and WST2, the wafer alignment/exchange sequence is completed before the exposure sequence. Therefore, wafer stage WST2 on which alignment has been completed moves into a waiting state at a predetermined waiting position.

[0108] Then, at the point where exposure of wafer W1 has been completed on the wafer stage WST1 side, main controller 20 begins to move wafer stages WST1 and WST2 toward a predetermined position shown in FIG. 6.

[0109] Then, after wafer stages WST1 and WST2 are moved to the position shown in FIG. 6, main controller 20 begins an operation of simultaneously driving wafer stages WST1 and WST2 in the +X direction. In the state shown in FIG. 6, wafer stage 5 WST1 and wafer stage WST2 are in contact via elastic seal member 93 applied to wafer stage WST1.

[0110] When main controller 20 simultaneously drives wafer stages WST1 and WST2 in the manner described above, in the state shown in FIG. 6, the water held in the space between tip lens 91 of projection unit PU and wafer W1 sequentially moves over the following areas along with the movement of wafer stages WST1 and WST2 to the +X side: wafer W1 → wafer stage WST1 (wafer holder H1, to be more specific) → wafer stage WST2 (wafer holder H2, to be more specific). During the movement, wafer stages WST1 and WST2 maintain the positional relation of being in contact via elastic seal member 93 as in the state shown in FIG. 6. FIG. 7 shows a state where the water simultaneously exists on both wafer stages WST1 and WST2 (wafer holders H1 and H2) during the movement above, that is, the state just before the water is passed over from wafer stage WST1 to wafer stage WST2.

[0111] When wafer stages WST1 and WST2 are further driven simultaneously by a predetermined distance in the +X direction from the state shown in FIG. 7, then the water moves into a state where it is held in the space between the area including fiducial mark plate FM2 on wafer stage WST2 and tip lens 91 as is shown in FIG. 8. And, prior to this state, main controller 20 resets Y-axis interferometer 46 at some point

where the interferometer beam from Y-axis interferometer begins to be irradiated on movable mirror 117Y.

[0112] Next, main controller 20 begins to drive wafer stage WST1 toward a right-hand side loading position shown 5 in FIG. 9. The right-hand side loading position is to be determined at a position directly under alignment system ALG1 where fiducial mark plate FM1 is positioned.

[0113] In parallel with starting to move wafer stage WST1 toward the right-hand side loading position, main 10 controller 20 detects the relative position between the first fiducial marks in pairs on fiducial mark plate FM2 and the projected images on the wafer surface of the reticle alignment marks on reticle R corresponding to the first fiducial marks with reticle alignment system RAa and RAb (refer to FIG. 1) 15 in pairs, using illumination light IL. On this detection, the first fiducial marks in pairs on fiducial mark plate FM2 and the images of the reticle alignment marks are detected via projection optical system PL and the water.

[0114] Then, based on the relative position 20 information that has been detected, the positional information of each shot area on wafer W2 with respect to the second fiducial marks obtained in advance, and the known positional relation between the first fiducial mark and the second fiducial mark, main controller 20 computes the relative 25 positional relation between the projection position (the projection center of projection optical system PL) of the pattern of reticle R and each shot area on wafer W2. And, based on the computation results, main controller 20 transfers the

pattern of reticle R on each shot area of wafer W2 by the step-and-scan method while controlling the position of wafer stage WST2 on the second exposure coordinate system as in the case of wafer W1 described above.

5 [0115] In parallel with the operation on the wafer stage WST2 side described above, on the wafer stage WST1 side at the right-hand side loading position, wafer exchange is performed with a wafer carrier system (not shown), and at the same time, or immediately after the wafer exchange, main controller 20 performs detection of the second fiducial marks on fiducial mark plate FM1 using alignment system ALG1. Prior to the detection of the second fiducial marks, main controller 20 resets Y-axis interferometer 48. Then, main controller 20 performs EGA on W2 using alignment system ALG1 while 10 controlling the position of wafer stage WST1 on the first alignment coordinate system.
15

[0116] Hereinafter, main controller repeats the parallel operation performed on wafer stages WST1 and WST2 described above.

20 [0117] On the parallel processing using wafer stage WST1 and wafer stage WST2, during the period while the exposure of the wafer on one of the wafer stages is completed until the exposure of the wafer on the other wafer stage is started, transition from a state where one of the wafer stages is 25 directly under projection unit PU (that is, a state where the water is located on one of the wafer stages) to a state where the other wafer stage is directly under projection unit PU (that is, a state where the water is located on the other wafer

stage) is performed. During this transition, the state where wafer stage WST1 and wafer stage WST2 are in contact in the X-axis direction via elastic seal member 93 (the state shown in FIG. 10) is maintained as is previously described.

5 Therefore, even if a state where the water crosses both wafer stages WST1 and WST2 occurs as is shown in FIG. 7, elastic seal member 93 prevents the water (liquid) from leaking under the stage via the gap between wafer stages WST1 and WST2 without fail.

10 [0118] While wafer stage WST1 and wafer stage WST2 are being moved, a state (moving period, moving interval) occurs where the interferometer beams from both Y-axis interferometers 46 and 48 do not irradiate movable mirror 17Y of wafer stage WST1, and a state (moving period, moving interval) also occurs where the interferometer beams from both Y-axis interferometers 46 and 44 do not irradiate movable mirror 117Y of wafer stage WST2. In the embodiment, however, a linear encoder (not shown) controls the position of both of the stages WST1 and WST2 in such a state. In the case the 15 linear encoder controls the position of the wafer stages, main controller 20 resets the Y-axis interferometer at the point where the interferometer beam from either of the Y-axis interferometers begins to irradiate movable mirrors 17Y or 117Y.

20 [0119] As is obvious from the description so far, in the embodiment, wafer stage drive section 124 and main controller 20 configure a stage drive system.

[0120] As is described above in detail, according to

exposure apparatus 100 and the drive method of wafer stages WST1 and WST2 executed in exposure apparatus 100 of the embodiment, when a transition is performed from a first state where one of the wafer stages WST1 (or WST2) is positioned 5 at a first area including the position (the first position) directly under projection unit PU to which the liquid (water) is supplied to a second state where the other wafer stage WST2 (or WST1) is positioned at the first area, the stage drive system (20, 124) simultaneously drives wafer stages WST1 and 10 WST2 in the X-axis direction (the first axis direction) while maintaining the state where wafer stage WST1 and wafer stage WST2 are in contact in the X-axis direction via elastic seal member 93.

[0121] Therefore, it becomes possible to perform the 15 transition from the first state where one of the wafer stages WST1 (or WST2) is positioned at the first area to a second state where the other wafer stage WST2 (or WST1) is positioned at the first area in a state where the water continues to be supplied to the space between projection optical system PL 20 (projection unit PU) and the specific wafer stage (this stage switches from one of the wafer stages to the other wafer stage with the movement) directly below projection optical system PL without leaking any water from the gap between the wafer stages. More specifically, the transition from a state where 25 the water is held in the space between one of the wafer stages and projection optical system PL to a state where the water is held in the space between the other wafer stage and projection optical system PL can be performed during the period

after the exposure operation of the wafer on one of the wafer stages via projection optical system PL and the water (liquid) has been completed until the exposure of the wafer on the other wafer stage via projection optical system PL and the water 5 (liquid) is started, without going through the process of fully recovering the water and then supplying the water again.

[0122] Accordingly, it becomes possible to improve the throughput by reducing the time that does not perform immersion exposure) from after the completion of the exposure 10 operation on one of the wafer stages until the beginning of the exposure operation on the other wafer stage. Further, because the water constantly exists on the image plane side of projection optical system PL, generation of water stains (water marks) on the optical members (e.g. tip lens 92, the 15 prisms of the multiple point focal position detection system previously described, or the like) on the image plane side of projection optical system PL can be effectively prevented, which allows the image-forming performance of projection optical system PL and the detection accuracy of the multiple 20 point focal position detection system to be favorably maintained for over a long period of time.

[0123] Further, the parallel processing operation of wafer stages WST1 and WST2 can improve the throughput of the exposure apparatus improved when compared with a conventional 25 exposure apparatus that has a single wafer stage and sequentially performs wafer exchange, wafer alignment, and exposure operations using the single wafer stage.

[0124] Further, by performing exposure with high

resolution and a larger depth of focus than in the air by the immersion exposure, the pattern of reticle R can be transferred with good precision on the wafer, and for example, transfer of a fine pattern that has a device rule of around 70 to 100
5 nm can be achieved.

[0125] Further, in the embodiment, because wafer stage WST1 and wafer stage WST2 are in contact via elastic seal member 93, water leakage from the gap between both stages can be suppressed, and in addition, the damper effect of
10 elastic seal member 93 can reduce the impact when wafer stage WST1 and wafer stage WST2 comes into contact.

[0126] Furthermore, in the embodiment, because there are no movable mirrors for the interferometers on the -X side surface of wafer stage WST1 and the +X side surface of wafer stage WST2, the reflection surfaces of the movable mirrors on both wafer stages do not face each other closely together even when both stages are close together in the X-axis direction. This allows not only the position of both stages to be monitored by interferometer system 118 while both wafer
15 stages are driven simultaneously in the X-axis direction, but also prevents the water from adhering to the reflection surface.
20

[0127]

<<Second Embodiment>>

25 Next, a second embodiment of the present invention will be described, referring to FIGS. 11 to 15(B). For parts that have the same or similar arrangement as the first embodiment previously described, the same reference numerals

will be used, and the description thereabout will be brief, or entirely omitted. In the exposure apparatus of the second embodiment, the configuration or the like of the wafer stage unit and the parallel processing operation using the two wafer 5 stages differ from the first embodiment previously described. Further, the point where only one mark detection system is arranged is also different from the first embodiment previously described. The configuration or the like of other components or assemblies are similar to the first embodiment 10 previously described. Accordingly, from the viewpoint of avoiding repetition in the following description, the differences will mainly be described.

[0128] FIG. 11 shows an arrangement of a control system in the exposure apparatus of the second embodiment. 15 When FIG. 11 is compared to FIG. 5, it can be seen that in the second embodiment, instead of wafer stage drive section 124 in the first embodiment previously described, the point where a wafer stage drive section 124A is arranged is different from the first embodiment previously described.

20 [0129] In the second embodiment, instead of wafer stage unit 50 described earlier, a wafer stage unit 50' shown in FIG. 12 is arranged. As is shown in FIG. 12, wafer stage unit 50' is equipped with a base platform 12, wafer stage WST1' serving as a first stage and wafer stage WST2' serving as a 25 second stage arranged above (the front side of the page surface of FIG. 12) the upper surface of base platform 12, six interferometers 151X₁, 151X₂, 151X₃, 151X₄, 151Y₁, and 151Y₂ serving as position measuring unit for measuring the positions

of wafer stages WST1' and WST2', a first drive section 171 and a second drive section 172 shaped roughly in a letter H in a planar view (when viewed from above) that individually drive wafer stages WST1' and WST2', and a first connecting mechanism 195 and a second connecting mechanism 196 (refer to FIG. 11).

[0130] In this case, the six interferometers 151X₁, 151X₂, 151X₃, 151X₄, 151Y₁, and 151Y₂ referred to above constitute an interferometer system 118A shown in FIG. 11, and wafer stage drive section 124A shown in FIG. 11 is configured including the first drive section 171, the second drive section 172, the first connecting mechanism 195, and the second connecting mechanism 196.

[0131] The first drive section 171 is equipped with an X-axis linear motor 136X serving as a linear actuator for driving wafer stage WST1' (or WST2') in the X-axis direction, and Y-axis linear motors 136Y₁ and 136Y₂ in pairs that integrally drive wafer stage WST1' (or WST2') in the Y-axis direction, which is the scanning direction, with X-axis linear motor 136X.

[0132] X-axis linear motor 136X is equipped with an X-axis linear guide 181 serving as a stator whose longitudinal direction is the X-axis direction, and an X mover 179 that moves in the X-axis direction along X-axis linear guide 181.

[0133] X-axis linear guide 181 is composed of a housing that extends in the X-axis direction, and an armature unit that has a plurality of armature coils arranged along the X-axis direction at a predetermined distance inside the

housing. On one end of X-axis linear guide 181 in the longitudinal direction (the X-axis direction), a mover (Y mover) 184 of one of the Y-axis linear motors, 136Y₁, is fixed, and on the other end, a mover (Y mover) 185 of the other Y-axis linear motor, 136Y₂, is fixed.

[0134] X mover 179, for example, has a cylindrical shape that surrounds X-axis linear guide 181 from all around, and inside X mover 179 a mover yoke whose YZ sectional surface is a reversed U-shape is arranged. In the mover yoke, a plurality of N-pole permanent magnets and S-pole permanent magnets are arranged alternately along the longitudinal direction. Therefore, in the space inside X mover 179, an alternating magnetic field is formed along the X-axis direction.

[0135] In this case, by the electromagnetic interaction between X-mover 179 and X-axis linear guide 181, a drive force (Lorentz force) that drives X mover 179 in the X-axis direction is generated. That is, X-axis linear motor 136X is a moving magnet type linear motor by the electromagnetic drive method.

[0136] On the -Y side surface of X mover 179, the first connecting mechanism 195 (not shown in FIG. 12, refer to FIG. 11) for connecting wafer stage WST1' (or WST2') is arranged. As the first connecting mechanism 195, for example, a mechanism that uses the electromagnetic suction of an electromagnet or a mechanism that mechanically engages wafer stage WST1' (or WST2') can also be used. Main controller 20 controls the first connecting mechanism 195 so as to connect X mover 179 to wafer

stage WST1' (or WST2') or to release the connection.

Incidentally, in a connected state, wafer stage WST1' (or WST2') is in a state where it is cantilevered by X mover 179.

FIG. 12 shows the state where X mover 179 cantilevers wafer
5 stage WST1' (or WST2').

[0137] One of the Y-axis linear motors 136Y₁ is equipped with a Y-axis linear guide 188 serving as a stator arranged extending in the Y-axis direction, and a Y mover 184 that moves along Y-axis linear guide 188. As Y-axis linear 10 guide 188, an armature unit having a similar arrangement as X-axis linear guide 181 previously described is used. Further, as Y mover 184, a magnetic pole unit having a similar arrangement as X mover 179 previously described but with a reversed U-shape in the XZ section is used. That is, Y-axis 15 linear motor 136Y₁ is a moving magnet type linear motor by the electromagnetic drive method.

[0138] The other Y-axis linear motor 136Y₂ is equipped with a Y-axis linear guide 189 serving as a stator arranged extending in the Y-axis direction, and a Y mover 185 that moves 20 along Y-axis linear guide 189. Y-axis linear motor 136Y₂ is also a moving magnet type linear motor by the electromagnetic drive method that is configured in a similar manner as Y-axis linear motor 136Y₁.

[0139] Further, because both ends of X-axis linear 25 guide 181 are respectively fixed to movers 184 and 185 as is previously described, when Y-axis linear motors 136Y₁ and 136Y₂ generate a drive force in the Y-axis direction, wafer stage WST1' (or WST2') is also driven in the Y-axis direction with

X-axis linear motor 136X. In this case, by making Y-axis linear motors 36Y₁ and 36Y₂ generate different drive forces, the rotation around the Z-axis of wafer stage WST1' (or WST2') can be controlled via X-axis liner motor 36X.

5 [0140] The second drive section 172 is arranged on the -Y side of the first drive section 171 described earlier, arranged substantially diphycercal within the page surface of FIG. 12. The second drive section 172 is configured in a similar manner as the first drive section 171 described above.

10 More specifically, the second drive section 172 is equipped with an X-axis linear motor 138X serving as a linear actuator configured of an X-axis linear guide 180 and an X mover 178, a Y-axis linear motor 138Y₁ configured of a Y mover 182 arranged on one end of X-axis linear guide 180 and a Y-axis linear guide 186, and a Y-axis linear motor 138Y₂ configured of a Y mover 183 arranged on the other end of X-axis linear guide 180 and a Y-axis linear guide 187.

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[0141] Similar to X mover 179, on the +Y surface side of X mover 178, the second connecting mechanism 196 (not shown in FIG. 12, refer to FIG. 11) similar to the first connecting mechanism 195 for connecting wafer stage WST1' (or WST2') is arranged. Main controller 20 controls the second connecting mechanism 196 so as to connect X mover 178 to wafer stage WST2' (or WST1') or to release the connection. FIG. 12 shows a supported state where X mover 178 is connected to wafer stage WST2' and is cantilevered.

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[0142] Wafer stage WST1' is configured of a stage main body without any magnetic pole units arranged, which is

different from the stage main body constituting wafer stage WST1 of the first embodiment previously described, and a wafer table similar to the wafer table constituting wafer stage WST1 previously described arranged on the upper surface of the stage 5 main body via a Z-tilt drive mechanism (not shown). On the upper surface of the wafer table, a +Y movable mirror 47Y₁, -Y movable mirror 47Y₂, and a +X movable mirror 47X are arranged in the vicinity of the edge section on the ±Y side and the +X side.

10 [0143] Wafer stage WST2' has an arrangement similar to wafer stage WST1' referred to above. On the upper surface of the wafer table constituting wafer stage WST2', a +Y movable mirror 49Y₁, -Y movable mirror 49Y₂, and a -X movable mirror 49X are arranged in the vicinity of the edge section on the 15 ±Y side and the +X side.

[0144] In the second embodiment as well, an elastic seal member similar to elastic seal member 93 shown in FIG. 10 is arranged on at least either the side surface of wafer stage WST1' on which the movable mirror is not arranged (the 20 -X side surface) or the side surface of wafer stage WST2' on which the movable mirror is not arranged (the +X side surface).

25 [0145] Further, as is shown in FIG. 12, an alignment system ALG serving as a mark detection system is arranged on the -Y side of projection optical system PL a predetermined distance away.

[0146] As is shown in FIG. 12, interferometer system 118A has two Y-axis interferometers 151Y₁ and 151Y₂ whose measurement axes are parallel to the Y-axis. The measurement

axes respectively pass through the projection center of projection optical system PL (optical axis AX) and the detection center of alignment system ALG. Interferometer system 118A also has two X-axis interferometers 151X₁ and 151X₂ whose measurement axes are parallel to the X-axis. The measurement axes also respectively cross the measurement axis of interferometer 151Y₁ perpendicularly at the projection center of projection optical system PL (optical axis AX). Interferometer system 118A also has two more X-axis interferometers 151X₃ and 151X₄ whose measurement axes are parallel to the X-axis. The measurement axes also respectively cross the measurement axis of interferometer 151Y₂ perpendicularly at the detection center of alignment system ALG.

[0147] The four X-axis interferometers 151X₁ to 151X₄ are multi-axis interferometers that have a plurality of optical axes, and the output values of each optical axis can be measured independently. Accordingly, with the four X-axis interferometers 151X₁ to 151X₄, other than measuring the position of wafer stages WST1' and WST2' in the X-axis direction, the rotation amount around the Y-axis (rolling amount) and the rotation amount around the Z-axis (yawing amount) can also be measured.

[0148] The two Y-axis interferometers 151Y₁ and 151Y₂ are dual-axis interferometers, for example, each having two optical axes, and the output values of each optical axis can be measured independently. Accordingly, with the Y-axis interferometers 151Y₁ and 151Y₂, other than measuring the

position of wafer stages WST1' and WST2' in the Y-axis direction, the rotation amount around the X-axis (pitching amount) can also be measured.

[0149] In this case, when wafer stage WST1' is in the 5 area (a first area) in the vicinity of the position (the first position) directly under the optical axis of projection optical system PL and exposure of the wafer on wafer stage WST1' (wafer W1 in FIG. 12) is to be performed, the position of wafer stage WST1' within the XY plane is controlled on a 10 first exposure coordinate system, which is set by the measurement axes of X-axis interferometer 151X₁ and Y-axis interferometer 151Y₁.

[0150] Further, when wafer stage WST2' is in the area 15 (a first area) in the vicinity of the position (the first position) directly under the optical axis of projection optical system PL and exposure of the wafer on wafer stage WST2' (wafer W2 in FIG. 12) is to be performed, the position of wafer stage WST2' within the XY plane is controlled on a second coordinate system, which is set by the measurement axes 20 of X-axis interferometer 151X₂ and Y-axis interferometer 151Y₁.

[0151] Further, when wafer stage WST1' is in the area 25 (a second area) in the vicinity of the position directly under the detection center of alignment system ALG, and in the case such as when alignment (EGA) of the wafer on wafer stage WST1' (wafer W1 in FIG. 12) is to be performed, the position of wafer stage WST1' within the XY plane is controlled on a first alignment coordinate system, which is set by the measurement

axes of X-axis interferometer 151X₃ and Y-axis interferometer 151Y₂.

[0152] Furthermore, when wafer stage WST2' is in the area (a second area) in the vicinity of the position directly under the detection center of alignment system ALG, and in the case such as when alignment (EGA) of the wafer on wafer stage WST2' (wafer W2 in FIG. 12) is to be performed, the position of wafer stage WST2' within the XY plane is controlled on a second alignment coordinate system, which is set by the measurement axes of X-axis interferometer 151X₄ and Y-axis interferometer 151Y₂.

[0153] The other sections in the configuration including liquid supply/drainage system 32 are configured in the same manner as in the first embodiment previously described.

[0154] Next, a series of operations including a parallel processing operation such as an exposure operation of a wafer on one of the wafer stages and an alignment operation of a wafer on the other wafer stage will be described, referring to FIGS. 12 to 15(B). During the operation below, main controller 20 performs the open/close operation of each valve in liquid supply unit 5 and liquid recovery unit 6 of liquid supply/drainage system 32 according to the moving direction of the wafer stages positioned at the first area directly under projection unit PU as is previously described, and the space directly under a tip lens 91 of projection optical system PL is constantly filled with the water. However, in the description below, for the sake of simplicity, the description

related to the control of liquid supply unit 5 and liquid recovery unit 6 will be omitted.

[0155] While wafer stage WST1' and wafer stage WST2' are being moved, an interval exists where the interferometer beams from the X-axis interferometer or the Y-axis interferometer does not irradiate the movable mirrors and position control of the wafer stages by the interferometers becomes difficult. In such a case, the position of the wafer stages is controlled by a linear encoder (not shown), and in the case the linear encoder controls the position of the wafer stages, main controller 20 resets the desired interferometer at the point where the interferometer beam from the desired interferometer begins to irradiate the movable mirrors. However, in the description below, in order to avoid complication, the description related to measuring the position of the wafer stages by the linear encoder and the reset of the interferometers will be omitted.

[0156] FIG. 12 shows a state where exposure of wafer W1 mounted on wafer stage WST1' is performed in the manner similar to the first embodiment described earlier by the step-and-scan method, while in parallel with this operation on the wafer stage WST2' side, wafer alignment of wafer W2 is performed at the second area below alignment system ALG.

[0157] Main controller 20 performs the exposure operation of wafer W1 while moving wafer stage WST1' by controlling the drive of X-axis linear motor 136, and Y-axis linear motors 136Y₁ and 136Y₂ in pairs, while controlling the position of wafer stage WST1' on the first exposure coordinate

system.

[0158] While exposure is being performed on wafer W1 by the step-and-scan method on the wafer stage WST1' side, the following operation is performed on the wafer stage WST2' 5 side.

[0158] More specifically, prior to the wafer alignment described above, at a predetermined loading position, wafer exchange is performed between a wafer carrier mechanism (not shown) and wafer stage WST2'.

10 [0160] After wafer exchange, main controller 20 executes the EGA previously described which includes detection the positional information of the sample marks arranged in the specific plurality of sample shot areas on wafer W2 using alignment system ALG while controlling the 15 position of wafer stage WST2' on the second alignment coordinate system referred to earlier, and computes the position coordinates of a plurality of shot areas on wafer W2 on the second alignment coordinate system. FIG. 12 shows a state during detection of the positional information of the 20 sample marks. Further, around the time of detection of the positional information of the sample marks, main controller 20 detects the positional information of the second fiducial marks formed on a fiducial mark plate FM2 on wafer stage WST2'. Then, main controller 20 converts the position coordinates 25 of the plurality of shot areas on wafer W2 obtained in advance into position coordinates using the position of the second fiducial marks as its origin.

[0161] The movement of wafer stage WST2' on the wafer

alignment or the like described above is performed by main controller 20, by driving and controlling X-axis linear motor 138X, and Y-axis linear motors 138Y₁ and 138Y₂ in pairs previously described.

5 [0162] Normally, in the wafer alignment operation of wafer W2 on wafer stage WST2' and the exposure operation of wafer W1 on wafer stage WST1', the wafer alignment operation is completed before the exposure operation. Therefore, after the wafer alignment has been completed, main controller 20
10 moves wafer stage WST2' to a predetermined waiting position shown in FIG. 13(A) via X-axis linear motor 138X, and Y-axis linear motors 138Y₁ and 138Y₂ in pairs, and makes wafer stage WST2' wait at the position.

15 [0163] Then, when the exposure operation of wafer W on wafer stage WST1' is completed, main controller 20 moves wafer stage WST1' to the position shown in FIG. 13(A) via X-axis linear motor 136, and Y-axis linear motors 136Y₁ and 136Y₂ in pairs. The exposure completion position of wafer W1 is preferably set in the vicinity of the position shown in FIG.
20 13(A).

[0164] After moving wafer stage WST1' to the position shown in FIG. 13(A), main controller 20 moves wafer stage WST2' via X-axis linear motor 138, and Y-axis linear motors 138Y₁ and 138Y₂ in pairs to a position shown in FIG. 13(B). In the
25 state where wafer stage WST2' has moved to the position shown in FIG. 13(B), wafer stage WST1' and wafer stage WST2' are in contact via the elastic seal member as in the first embodiment previously described.

[0165] Next, main controller 20 simultaneously moves wafer stage WST1' and wafer stage WST2' in the +X direction by controlling X-axis linear motor 136, and Y-axis linear motors 136Y₁ and 136Y₂ in pairs, and X-axis linear motor 138, 5 and Y-axis linear motors 138Y₁ and 138Y₂ in pairs. FIG. 14 (A) shows a state where both wafer stages WST1' and WST2' have been moved simultaneously in the +X direction from the state shown in FIG. 13(B) and the water is held in the space between the area including fiducial mark plate FM2 on wafer stage WST2' 10 and tip lens 91.

[0166] In the state shown in FIG. 13(B), the water that has been held or retained in the space between tip lens 91 of projection unit PU and wafer W1 sequentially moves over the following areas along with the movement of wafer stages 15 WST1' and WST2' to the +X side: wafer W1 → wafer stage WST1' → wafer stage WST2'. During the movement, wafer stages WST1' and WST2' maintain the positional relation of being in contact via elastic seal member 93.

[0167] Next, main controller 20 releases the 20 connected state of X mover 179 and wafer stage WST1' by the first connecting mechanism 195 and the connected state of X mover 178 and wafer stage WST2' by the second connecting mechanism 196, and after this operation, main controller 20 slightly moves X mover 179 in the +Y direction and X mover 25 178 in the -Y direction. FIG. 14(B) shows the state after the X movers 179 and 178 have been driven or moved.

[0168] In the state shown in FIG. 14(B), wafer stages WST1' and WST2' are supported by levitation above base platform

12 by air pads (not shown) arranged on each of the bottom surfaces (the surface on the -Z side) of wafer stages WST1' and WST2'. However, without limitation to this configuration, support legs that can freely appear can be 5 arranged on the wafer stages WST1' and WST2' side or on the base platform 12 side, and wafer stages WST1' and WST2' can be stably supported above base platform 12 by the legs just before the connections between wafer stage WST1' and X mover 179 and wafer stage WST2' and X mover 178 are released.

10 [0169] Next, main controller 20 drives X mover 179 via Y-axis linear motors 136Y₁ and 136Y₂ in pairs and X-axis linear motor 136, and moves X mover 179 to a position where it can be connected to wafer stage WST2', and also drives X mover 178 via Y-axis linear motors 138Y₁ and 138Y₂ in pairs 15 and X-axis linear motor 138, and moves X mover 178 to a position where it can be connected to wafer stage WST1'. At this point, the encoder (not shown) controls the position of each X mover.

20 [0170] FIG. 15(A) shows the state where X mover 179 is driven and moved to a position where it can be connected to wafer stage WST2', while X mover 178 is driven and moved to a position where it can be connected to wafer stage WST1' in the manner described above. Then, main controller 20 connects X mover 179 to wafer stage WST1' via the first connecting mechanism 195, and also connects X mover 178 to 25 wafer stage WST2' via the second connecting mechanism 196. The movement of X movers 178 and 179 in the X direction and the attach/release of wafer stages WST1 and WST2 can be performed without any movement in the Y-axis direction.

[0171] After wafer stage WST1' is connected to X mover 179 and wafer stage WST2' is connected to X mover 178 in the manner described above, main controller 20 measures the first fiducial mark in pairs on fiducial mark plate FM2 and the 5 reticle alignment marks in pairs on reticle R, using reticle alignment systems RAa and RAb, while controlling the position of wafer stage WST2' on the second exposure coordinate system previously described. Then, based on the measurement results and the results of the alignment performed earlier, main 10 controller 20 moves wafer stage WST2' to the acceleration starting position for exposing the first shot area on wafer W2. Then, main controller 20 drives and controls wafer stage WST2' via X-axis linear motor 136, and Y-axis linear motors 136Y₁ and 136Y₂ in pairs while controlling the position of wafer 15 stage WST2' on the second exposure coordinate system, and the exposure operation of wafer W2 is performed by the step-and-scan method in a similar manner as in the first embodiment previously described.

[0172] Meanwhile, main controller 20 moves wafer 20 stage WST1' toward a loading position via Y-axis linear motors 138Y₁ and 138Y₂, and X-axis linear motor 136. The position of wafer stage WST1' during this movement is controlled on the first alignment coordinate system. And, at the loading position, after wafer exchange of wafer W1 on wafer stage WST1' 25 that has been exposed and the next wafer subject to exposure has been performed, main controller 20 performs the wafer alignment operation on the new wafer in a similar manner as the description above.

[0173] Then, at the point where wafer alignment of wafer stage WST1' has been completed and the exposure operation on wafer stage WST2' has been completed, wafer stage WST1' and wafer stage WST2' follow the paths described above 5 completely backwards, and return to the state shown in FIG. 12.

[0174] As is described above, in the exposure apparatus of the second embodiment, the exposure operation of a wafer on one stage and the wafer exchange and wafer 10 alignment operation on the other stage is performed in a simultaneous parallel processing, while performing a switching operation (switching) between wafer stages WST1' and WST2'.

[0175] As is obvious from the description so far, in 15 the second embodiment, a stage drive system is configured by wafer stage drive section 124A and main controller 20. Further, a switching unit is configured by the first connecting mechanism 195, the second connecting mechanism 196, Y-axis 20 linear motors 136Y₁ to 136Y₄, and main controller 20 for controlling the parts above.

[0176] As is described above in detail, according to the exposure apparatus and the drive method of wafer stages WST1' and WST2' executed by the exposure apparatus in the second embodiment, during transition from the first state in 25 which one of the wafer stages WST1' (or WST2') is positioned at the first area that includes the first position directly under projection optical system PL where the liquid is supplied to the second state in which the other stage WST2' (or WST1')

is positioned at the first area, the stage drive system (20, 124A) simultaneously drives wafer stages WST1' and WST2' in the X-axis direction while maintaining the state of wafer stages WST1' and WST2' being in contact in the X-axis direction 5 (the second axis direction) (the direction that intersects the Y-axis direction (the first axis direction) in which the first area and the second area close to the position directly under the alignment system ALG are lined) via elastic seal member 93.

10 [0177] Therefore, it becomes possible to perform the transition from the first state in which one of the wafer stages WST1' (or WST2') is positioned at the first area to the second state in which the other stage WST2' (or WST1') is positioned at the first area, in a state where the water (liquid) is 15 supplied in the space between projection optical system PL and the specific wafer stage directly below projection optical system PL (this stage switches from one of the wafer stages to the other wafer stages due to the movement of the stages), without leaking the liquid from the gap between both stages. 20 More specifically, the transition from a state where the water is held in the space between one of the wafer stages and projection optical system PL to a state where the water is held in the space between the other wafer stage and projection optical system PL can be performed during the period after 25 the exposure operation of the wafer on one of the wafer stages via projection optical system PL and the water (liquid) has been completed until the exposure of the wafer on the other wafer stage via projection optical system PL and the water

(liquid) is started, without going through the process of fully recovering the water and then supplying the water again. Accordingly, it becomes possible to improve the throughput by reducing the time from after the completion of the exposure 5 operation on one of the wafer stages until the beginning of the exposure operation on the other wafer stage. Further, because the water constantly exists on the image plane side of projection optical system PL, for the same reasons as in the first embodiment previously described, the image-forming 10 performance of projection optical system PL and the detection accuracy of the multiple point focal position detection system can be favorably maintained for over a long period of time.

[0178] Further, the parallel processing operation of wafer stages WST1' and WST2' can improve the throughput of 15 the exposure apparatus improved when compared with a conventional exposure apparatus that has a single wafer stage and sequentially performs wafer exchange, wafer alignment, and exposure operations using the single wafer stage.

[0179] Further, also in the exposure apparatus of the 20 second embodiment, by performing exposure with high resolution and a larger depth of focus than in the air by the immersion exposure, the pattern of reticle R can be transferred with good precision on the wafer.

[0180] Further, also in the second embodiment, for 25 the same reasons as in the first embodiment previously described, water leakage from the gap between both stages can be suppressed, and in addition, the impact when wafer stage WST1 and wafer stage WST2 comes into contact can be reduced.

[0181] Furthermore, also in the second embodiment, because there are no movable mirrors for the interferometers on the -X side surface of wafer stage WST1' and the +X side surface of wafer stage WST2' as in the first embodiment 5 previously described, the reflection surfaces of the movable mirrors on both wafer stages do not face each other closely together even when both stages are close together in the X-axis direction. This allows not only the position of both stages to be monitored by interferometer system 118A while both wafer 10 stages are driven simultaneously in the X-axis direction, but also prevents the water from adhering to the reflection surface.

[0182] In the second embodiment above, the case has been described where three movable mirrors are arranged on 15 both wafer stages WST1' and WST2' and six interferometers are arranged, however, the arrangement of the movable mirrors and the interferometers is not limited to the arrangement described in the second embodiment above. For example, two movable mirrors can be arranged on both of the stages, and 20 an arrangement of the interferometers that allows the position of both wafer stages to be measured using the respective mirrors can be employed.

[0183] Further, in the second embodiment above, the shifting by X movers 178 and 179 is performed after the water 25 held under tip lens 91 moves from above one of the stages to the other stage. The shifting by X movers 178 and 179, however, can be performed before the water moves from above one of the stages to the other stage.

[0184]

<<Third Embodiment>>

Next, a third embodiment of the present invention will be described, referring to FIGS. 16 to 18(B). For components or assemblies that have the same or similar arrangement as the first embodiment previously described, the same reference numerals will be used, and the description thereabout will be brief, or entirely omitted. In the exposure apparatus of the third embodiment, only the configuration or the like of the wafer stage unit differ from the first embodiment previously described, and the configuration or the like of other components are similar to the first embodiment previously described. Accordingly, from the viewpoint of avoiding repetition in the following description, the differences will mainly be described.

[0185] Different from wafer stage unit 50 that constitutes the exposure apparatus of the first embodiment previously described, as is shown in FIG. 16, a wafer stage unit 50" of the third embodiment is equipped with a wafer stage WST serving as a first stage on which a wafer can be loaded, and a measurement stage MST serving as a second stage used only for measurement.

[0186] Wafer stage WST and measurement stage MST correspond to wafer stage WST1 and wafer stage WST2 described earlier in the first embodiment, and are driven within a two-dimensional plane by a wafer stage drive section (80 to 87) similar to the drive section in the first embodiment.

[0187] Further, in the vicinity of a projection

optical system PL (the barrel of projection unit PU), only one alignment system ALG is arranged. Projection unit PU and alignment system ALG are actually arranged in a nested state, as is shown in FIG. 16.

5 [0188] On the upper surface of measurement stage MST, various measurement members are arranged. As such measurement members, for example, a fiducial mark plate on which a plurality of fiducial marks are formed or a sensor that receives illumination light IL via projection optical
10 system PL such as the ones disclosed in, for example, Kokai (Japanese Unexamined Patent Application Publication) No. 5-21314 (corresponding U.S. Patent No. 5,243,195) are included. As the sensor, an illumination monitor having a photodetection section of a predetermined area for receiving
15 illumination light IL on the image plane of projection optical system PL whose details are disclosed in Kokai (Japanese Unexamined Patent Application Publication) No. 11-16816 (corresponding U.S. Patent Application Publication No. 2002/0061469), an uneven illuminance measuring sensor, which
20 has a pinhole-shaped light-receiving section that receives illumination light IL on the image plane of projection optical system PL whose details are disclosed in Kokai (Japanese Unexamined Patent Application Publication) No. 57-117238 (corresponding U.S. Patent No. 4,465,368), or an aerial image
25 measuring instrument that measures the light intensity of the aerial image (projected image) of the pattern projected by projection optical system PL whose details are disclosed in Kokai (Japanese Unexamined Patent Application Publication)

No. 2002-14005 (corresponding U.S. Patent Application Publication No. 2002/0041377) can be employed.

[0189] In the embodiment, in response to the immersion exposure performed in which wafer W is exposed by 5 exposure light (illumination light) IL via projection optical system PL and water, the illumination monitor, the irregular illuminance measuring sensor, and the aerial image measuring instrument above used for measurement using illumination light IL are to receive illumination light IL via projection 10 optical system PL and the water. Further, only a part of each sensor, such as the optical system, can be arranged on measurement stage MST, or the whole sensor can be disposed on measurement stage MST.

[0190] Further, in the third embodiment, similar to 15 the first embodiment previously described, an elastic seal member similar to elastic seal member 93 in FIG. 10 is arranged on at least either the -X side surface of wafer stage WST or the +X side surface of measurement stage MST.

[0191] Hereinafter, details on a parallel processing 20 operation using wafer stage WST and measurement stage MST equipped in the exposure apparatus of the third embodiment will be described, referring to FIGS. 16 to 18(B). In the exposure apparatus related to the third embodiment as well, an interferometer system similar to the one used in the first 25 embodiment is arranged, and the position of wafer stage WST and measurement stage MST is controlled as in the first embodiment. In the description below, in order to prevent redundant explanation, the description related to controlling

the position of the stages by the interferometer system will be omitted. And, in the operation below, as is previously described, main controller 20 performs the open/close operation of each valve in liquid supply unit 5 and liquid recovery unit 6 of liquid supply/drainage system 32 according to the moving direction of the stage positioned at the first area directly under projection unit PU, and the space directly under tip lens 91 of projection optical system PL is constantly filled with the water. However, in the description below, for the sake of simplicity, the description related to the control of liquid supply unit 5 and liquid recovery unit 6 will be omitted.

[0192] FIG. 16 shows a state where exposure by the step-and-scan method is performed on wafer W in a manner similar to the first embodiment previously described. At this point, measurement stage MST is waiting at a predetermined waiting position where it does not bump into wafer stage WST.

[0193] Then, on the wafer stage WST side, for example, at the stage where exposure of one lot (25 or 50 wafers in one lot) of wafer W is completed, main controller 20 moves measurement stage MST to the position shown in FIG. 17(A). In the state shown in FIG. 16(A), measurement stage MST and wafer stage WST are in contact via the elastic seal member.

[0194] Next, main controller 20 begins the operation of simultaneously driving both stages WST and MST in the +X direction, while maintaining the positional relation between wafer stage WST and measurement stage MST in the X-axis direction.

[0195] When main controller 20 simultaneously drives wafer stage WST and measurement stage MST in the manner described above, in the state shown in FIG. 17(A), the water held in the space between tip lens 91 of projection unit PU 5 and wafer W sequentially moves over the following areas along with the movement of wafer stage WST and measurement stage MST to the +X side: wafer W → wafer stage WST → measurement stage MST. During the movement, wafer stage WST and measurement stage MST maintain the positional relation of 10 being in contact via the elastic seal member as in the state shown in FIG. 17(A). FIG. 17(B) shows a state where the water simultaneously exists on wafer stage WST and measurement stage MST during the movement above, that is, the state just before the water is passed over from wafer stage WST to measurement 15 stage MST.

[0196] When wafer stage WST and measurement stage MST are further driven simultaneously by a predetermined distance in the +X direction from the state shown in FIG. 17(B), then it becomes a state where the water is held in between 20 measurement stage MST and tip lens 91 as is shown in FIG. 18(A).

[0197] Next, main controller 20 moves wafer stage WST to a predetermined wafer exchange position and also exchanges the wafer, and in parallel with this, executes a predetermined measurement using measurement stage MST as necessary. As an 25 example of this measurement, baseline measurement of alignment system ALG performed after the reticle has been exchanged on reticle stage RST can be given. To be more specific, main controller 20 detects a first fiducial mark

in pairs on a fiducial mark plate FM arranged on measurement stage MST and the corresponding reticle alignment marks on the reticle at the same time using reticle alignment systems R_{Aa} and R_{Ab} previously described, and detects the positional relation between the first fiducial mark in pairs and the corresponding reticle alignment marks. And, at the same time, by also detecting second fiducial marks on fiducial mark plate FM with the alignment system ALG, main controller 20 detects the positional relation between the detection center of alignment system ALG and the second fiducial mark. Then, based on the positional relation between the first fiducial mark in pairs and the corresponding reticle alignment marks and the positional relation between the detection center of alignment system ALG and the second fiducial marks obtained above, and the known positional relation between the first fiducial mark in pairs and the second fiducial marks, main controller 20 obtains the distance between the projection center of the reticle pattern by projection optical system PL and the detection center of alignment system ALG, that is, obtains the baseline of alignment system ALG. FIG. 18(B) shows this state.

[0198] Reticle alignment marks in a plurality of pairs have been formed on the reticle and also the first fiducial mark in a plurality of pairs have been formed on fiducial mark plate FM corresponding to the retile alignment marks, and along with measuring the baseline of alignment system ALG described above, by measuring the relative position of at least two pairs of the first fiducial marks

and the corresponding reticle alignment marks using reticle alignment systems RAa and RAb while stepping reticle stage RST and wafer stage WST in the Y-axis direction, the so-called reticle alignment is performed.

5 [0199] In this case, mark detection using reticle alignment systems RAa and RAb is performed via projection optical system PL and the water.

[0200] Then, at the point where the operations described above on both stages WST and MST have been completed, 10 main controller 20 moves measurement stage MST and wafer stage WST, for example, within the XY plane while maintaining the state in which measurement stage MST and wafer stage WST are in contact via the elastic seal member, and then as is previously described, main controller 20 performs wafer 15 alignment on wafer W that has been exchanged, or in other words, performs detection of the alignment marks on wafer W that has been exchanged with alignment system ALG, and computes the position coordinates of a plurality of shot areas on wafer W.

20 [0201] Then, opposite to the operation above, main controller 20 simultaneously drives wafer stage WST and measurement stage MST in the -X direction while maintaining the positional relation of both stages in the X-axis direction, and then withdraws measurement stage MST to a predetermined 25 position after wafer stage WST (wafer W) moves to the position under projection optical system PL.

[0202] Then, main controller 20 performs the exposure operation by the step-and-scan method on wafer W, and

sequentially transfers the reticle pattern onto the plurality of shot areas on wafer W. Moving wafer stage WST to the acceleration starting position for exposing each shot area on wafer W is performed based on the position coordinates of 5 the plurality of shot areas on wafer W obtained by the wafer alignment above and on the baseline measured just before moving wafer stage WST.

[0203] In the description above, as the measurement operation, the case has been described where baseline 10 measurement has been performed. The measurement, however, is not limited to this, and measurements such as illuminance measurement, irregular illuminance measurement, aerial image measurement and the like can be performed using measurement stage MST, for example, in parallel with the wafer exchange, 15 and the measurement results can be reflected to the exposure of wafer W that will be performed after the measurement. Further, the sensor installed on measurement stage MST is not limited to the ones described above, and for example, a sensor that performs wavefront measurement can also be arranged.

20 [0204] Further, in the third embodiment described above, the case has been described where wafer stage WST and measurement stage MST are moved while in contact when exposure of one lot of wafer W has been completed, and the water is held between projection optical system PL and measurement 25 stage MST. However, it is a matter of course that the operation above should be performed each time the wafer is exchanged so as to hold the water between projection optical system PL and measurement stage MST. Further, measurement of the

baseline or the like can be performed when exposure of one lot has been completed as is previously described, or the measurement can be performed each time the wafer is exchanged or after the exposure of a predetermined number of wafers has 5 been completed.

[0205] As is obvious from the description so far, in the third embodiment, main controller 20 and a wafer stage drive section (80 to 87) configure a stage drive system as in the first embodiment.

10 [0206] As is described above, according to the exposure apparatus of the third embodiment, during a transition is performed from a first state where wafer stage WST (or measurement stage MST) positioned at a first area that includes the first position directly under projection unit PU to which the liquid (water) is supplied to a second state where measurement stage MST (or wafer stage WST) is positioned at the first area, the stage drive system described above simultaneously drives wafer stage WST and measurement stage MST in the X-axis direction while maintaining the state where 15 both stages are in contact in the X-axis direction (the first axis direction) via the elastic seal member. Therefore, it becomes possible to perform the transition from the first state where one of the stages is positioned at the first area to a second state where the other stage is positioned at the first 20 area in a state where the water continues to be supplied to the space between projection optical system PL and the specific stage (this stage switches from one of the stages to the other stage with the movement) directly below projection optical 25

system PL without leaking any water from the gap between both stages. More specifically, the transition from a state where the water is held in the space between wafer stage WST and projection optical system PL to a state where the water is
5 held in the space between measurement stage MST and projection optical system PL can be performed during the period after the exposure operation on the wafer stage WST side via projection optical system PL and the water (liquid) has been completed until the measurement on the measurement stage MST
10 side directly under projection optical system PL is started, without going through the process of fully recovering the water and then supplying the water again. Further, the same applies to after the measurement with measurement stage MST has been completed until the exposure by wafer stage WST begins.

15 [0207] Accordingly, it becomes possible to improve the throughput by reducing the time after the exposure operation on the wafer stage WST side has been completed until the measurement on the measurement stage MST side is started, and the time after the measurement with measurement stage MST
20 has been completed until the exposure by wafer stage WST begins. Further, because the water (liquid) constantly exists on the image plane side of projection optical system PL, generation of water stains (water marks) previously described can be effectively prevented.

25 [0208] Further, by performing exposure with high resolution and a larger depth of focus than in the air by the immersion exposure, the pattern of reticle R can be transferred with good precision on the wafer, and for example, transfer

of a fine pattern that has a device rule of around 70 to 100 nm can be achieved.

[0209] In the case illumination light IL is not used in the measurement operation performed using measurement stage MST, it is also possible to perform the measurement operation on the measurement stage side in parallel with the exposure operation on the wafer stage WST side.

[0210] Further, in the third embodiment above, wafer alignment is performed in a state where measurement stage MST and wafer stage WST are in contact via the elastic seal member. However, wafer alignment can also be performed by moving wafer stage WST under projection optical system PL in a state where the two stages are in contact before wafer alignment is performed, and then performing wafer alignment after the withdrawal of measurement stage MST.

[0211] Further, in the third embodiment described above, the first fiducial marks and the second fiducial marks on fiducial mark plate FM can be measured at the same time. However, after measuring one of the first fiducial marks or 20 the second fiducial marks, measurement stage MST can be moved in a state where the water is held on measurement stage MST so as to measure the other mark.

[0212] As the elastic seal member used in the first to third embodiments described above, as is shown in FIG. 19(A), 25 an elastic seal member 93' can be used, which is attached in an embedded state to a groove 49 whose sectional shape is a rough trapezoid and is formed on the +X side surface of one of the stages (in this case, stage WST2 (WST2', MST)). This

arrangement also allows the same effect to be obtained as in each of the embodiments above. The arrangement shown in FIG. 19(A) can be employed not only in one of the stages but also in both stages.

5 [0213] Further, as is show in FIG. 19(B), a groove 49' whose sectional shape is a rough trapezoid can be formed on the +X side surface of one of the stages (in this case, stage WST1 (WST1', WST)) and an elastic seal member 93" can be attached in an embedded state to groove 49', and a flat 10 plate 94 can be arranged on the edge of the upper surface of the other stage (in this case, stage WST2 (WST2', MST)) on the +X side. In this case, in a state where both stages are close together, the water can be kept from leaking from between the stages by flat plate 94 coming into contact with elastic 15 seal member 93", as is shown in FIG. 19(B).

[0214] Further, as is shown in FIG. 19(C), the entering and the leakage of the water into and from the gap between both stages can be prevented, for example, by applying a water-repellent coating 95 by Teflon (trademark) or the like 20 on the side surface of both of the stages facing each other. By this operation, because a non-contact state is maintained between both stages, there is no risk of stage deformation, decrease in position control accuracy or the like, due to the contact of both stages.

25 [0215] In each of the embodiments described above, the elastic seal member is arranged, however, the elastic seal member or other suppression members for suppressing leakage does not necessarily have to be arranged. In such a case, both

stages can be in contact directly while the transition is made from a state where one of the stages is located directly under projection unit PU to a state where the other stage is located directly under projection unit PU. Further, although it
5 depends on the material of both stages, and/or the type of liquid and the like, in the case the liquid does not leak due to the surface tension of the liquid during the transition in a state where both stages are close together (e.g. the distance between the stages is 2 mm or under), the
10 water-repellent coating does not have to be applied. The point is that the transition of both stages should be made while maintaining the positional relation, which keeps the liquid from leaking from between the stages.

[0216] Further, in each of the embodiments described
15 above, reflection surfaces of the movable mirrors are not formed on the contact surfaces of the two stages. However, this is not an indispensable matter, and as long as the leakage of the water from the gap in the two stages can be prevented, a reflection surface of the movable mirrors can be formed on
20 the contact surface of at least one of the stages.

[0217] In each of the embodiments described above, when the water held under tip lens 91 is moved from above one stage to above the other stage, the water supply and recovery can be stopped while the water is held under tip lens 91.
25 Especially in the case when the water pressure increases due to the supply of water, it makes the water leak more easily from the gap of the two stages. Therefore, the water supply and recovery are preferably stopped.

[0218] In each of the embodiments described above, pure water (water) is used as the liquid, however, as a matter of course, the present invention is not limited to this. As the liquid, a liquid that is chemically stable, having high transmittance to illumination light IL and safe to use, such as a fluorine containing inert liquid may be used. As such as a fluorine-containing inert liquid, for example, Fluorinert (the brand name of 3M United States) can be used. The fluorine-containing inert liquid is also excellent from the point of cooling effect. Further, as the liquid, a liquid which has high transmittance to illumination light IL and a refractive index as high as possible, and furthermore, a liquid which is stable against the projection optical system and the photoresist coated on the surface of the wafer (for example, cederwood oil or the like) can also be used. Further, in the case the F₂ laser is used as the light source, fombrin oil may be used as the fluorine containing liquid.

[0219] Further, in each of the embodiments above, the liquid that has been recovered may be reused. In this case, it is desirable to arrange a filter in the liquid recovery unit, in the recovery pipes, or the like for removing impurities from the liquid that has been recovered.

[0220] In each of the embodiments above, the optical element of projection optical system PL closest to the image plane side is tip lens 91. The optical element, however, is not limited to a lens, and it can be an optical plate (parallel plane plate) used for adjusting the optical properties of projection optical system PL such as aberration (such as

spherical aberration, coma, or the like), or it can also simply be a cover glass. The surface of the optical element of projection optical system PL closest to the image plane side (tip lens 91 in the embodiments above) can be contaminated by coming into contact with the liquid (water, in the embodiments above) due to scattered particles generated from the resist by the irradiation of illumination light IL or adherence of impurities in the liquid. Therefore, the optical element is to be fixed freely detachable (exchangeable) to the lowest section of barrel 40, and can be exchanged periodically.

[0221] In such a case, when the optical element that comes into contact with the liquid is a lens, the cost for replacement parts is high, and the time required for exchange becomes long, which leads to an increase in the maintenance cost (running cost) as well as a decrease in throughput. Therefore, for example, the optical element that comes into contact with the liquid can be a parallel plane plate, which is less costly than lens 91.

[0222] Further, in each of the embodiments above, the range of the liquid (water) flow only has to be set so that it covers the entire projection area (the irradiation area of illumination light IL) of the pattern image of the reticle. Therefore, the size may be of any size; however, on controlling the flow speed, the flow amount and the like, it is preferable to keep the range slightly larger than the irradiation area but as small as possible.

[0223] Further, in each of the embodiments above, the

case has been described where the present invention is applied to a scanning exposure apparatus by the step-and-scan method or the like. It is a matter of course, that the present invention is not limited to this, and more specifically, the 5 present invention can also be applied to a projection exposure apparatus by the step-and-repeat method

[0224] The usage of the exposure apparatus to which the present invention is applied is not limited to the exposure apparatus used for manufacturing semiconductor devices. For 10 example, the present invention can be widely applied to an exposure apparatus for manufacturing liquid crystal displays which transfers a liquid crystal display deice pattern onto a square shaped glass plate, and to an exposure apparatus for manufacturing organic EL, thin-film magnetic heads, imaging 15 devices (such as CCDs), micromachines, DNA chips or the like. Further, the present invention can also be suitably applied to an exposure apparatus that transfers a circuit pattern onto a glass substrate or a silicon wafer not only when producing microdevices such as semiconductors, but also when producing 20 a reticle or a mask used in exposure apparatus such as an optical exposure apparatus, an EUV exposure apparatus, an X-ray exposure apparatus, or an electron beam exposure apparatus.

[0225] Further, the light source of the exposure 25 apparatus in the embodiment above is not limited to the ArF excimer laser, and a pulsed laser light source such as a KrF excimer laser or an F₂ laser, or an ultra high-pressure mercury lamp that generates a bright line such as the g-line

(wavelength 436 nm) or the i-line (wavelength 365 nm) can also be used as the light source.

[0226] Further, a harmonic wave may also be used that is obtained by amplifying a single-wavelength laser beam in 5 the infrared or visible range emitted by a DFB semiconductor laser or fiber laser, with a fiber amplifier doped with, for example, erbium (or both erbium and ytteribium), and by converting the wavelength into ultraviolet light using a nonlinear optical crystal. Further, the projection optical 10 system is not limited to a reduction system, and the system may be either an equal magnifying system or a magnifying system.

[0227]

<<Device Manufacturing Method>>

15 Next, an embodiment will be described of a device manufacturing method that uses the exposure apparatus described in each of the embodiments above in the lithography step.

[0228] FIG. 20 shows the flowchart of an example when 20 manufacturing a device (a semiconductor chip such as an IC or an LSI, a liquid crystal panel, a CCD, a thin-film magnetic head, a micromachine, and the like). As shown in FIG. 20, in step 201 (design step), function and performance design of device (circuit design of semiconductor device, for example) 25 is performed first, and pattern design to realize the function is performed. Then, in step 202 (mask manufacturing step), a mask on which the designed circuit pattern is formed is manufactured. Meanwhile, in step 203 (wafer manufacturing

step), a wafer is manufactured using materials such as silicon.

[0229] Next, in step 204 (wafer processing step), the actual circuit and the like are formed on the wafer by lithography or the like in a manner that will be described 5 later, using the mask and the wafer prepared in steps 201 to 203. Then, in step 205 (device assembly step), device assembly is performed using the wafer processed in step 204. Step 205 includes processes such as the dicing process, the bonding process, and the packaging process (chip 10 encapsulation), and the like when necessary.

[0230] Finally, in step 206 (inspection step), tests on operation, durability, and the like are performed on the devices made in step 205. After these steps, the devices are completed and shipped out.

15 [0231] FIG. 21 is a flow chart showing a detailed example of step 204 described above. Referring to FIG. 21, in step 211 (oxidation step), the surface of wafer is oxidized. In step 212 (CDV step), an insulating film is formed on the wafer surface. In step 213 (electrode formation step), an 20 electrode is formed on the wafer by deposition. In step 214 (ion implantation step), ions are implanted into the wafer. Each of the above steps 211 to 214 constitutes the pre-process in each step of wafer processing, and the necessary processing is chosen and is executed at each stage.

25 [0232] When the above-described pre-process ends in each stage of wafer processing, post-process is executed as follows. In the post-process, first in step 215 (resist formation step), a photosensitive agent is coated on the wafer.

Then, in step 216 (exposure step), the circuit pattern of the mask is transferred onto the wafer by the lithography system (exposure apparatus) and the exposure method of the embodiment above. Next, in step 217 (development step), the exposed 5 wafer is developed, and in step 218 (etching step), an exposed member of an area other than the area where resist remains is removed by etching. Then, in step 219 (resist removing step), when etching is completed, the resist that is no longer necessary is removed.

10 [0233] By repeatedly performing the pre-process and the post-process, multiple circuit patterns are formed on the wafer.

[0234] When the device manufacturing method of the embodiment described so far is used, using the exposure 15 apparatus in each of the embodiments above in the exposure step (step 216), exposure with high throughput and high precision can be achieved for a long period of time. Accordingly, the productivity of high integration microdevices on which fine patterns are formed can be improved.

20

[INDUSTRIAL APPLICABILITY]

[0235] As is described above, the stage drive method of the present invention is suitable for driving the first stage and the second stage. Further, the exposure apparatus 25 of the present invention is suitable for supplying liquid in the space between the projection optical system and the substrate and exposing the substrate with the energy beam via the projection optical system and the liquid. Further, the

device manufacturing method of the present invention is suitable for producing microdevices.

[BRIEF DESCRIPTION OF THE DRAWINGS]

5 [0236]

[FIG. 1] FIG. 1 is a schematic view showing a configuration of an exposure apparatus related to a first embodiment.

10 **[FIG. 2]** FIG. 2 is a planar view showing a wafer stage unit related to the first embodiment.

[FIG. 3] FIG. 3 is a perspective view showing a wafer stage WST1 in FIG. 2.

[FIG. 4] FIG. 4 is a rough planar view of a liquid supply/drainage mechanism.

15 **[FIG. 5]** FIG. 5 is a block diagram showing the main configuration of a control system of the exposure apparatus in the first embodiment.

[FIG. 6] FIG. 6 is a view (No. 1) for describing a drive method of two wafer stages in a parallel processing operation.

20 **[FIG. 7]** FIG. 7 is a view (No. 2) for describing a drive method of two wafer stages in a parallel processing operation.

[FIG. 8] FIG. 8 is a view (No. 3) for describing a drive method of two wafer stages in a parallel processing operation.

25 **[FIG. 9]** FIG. 9 is a view (No. 4) for describing a drive method of two wafer stages in a parallel processing operation.

[FIG. 10] FIG. 10 is a view showing an elastic seal member.

[FIG. 11] FIG. 11 is a block diagram showing the main

configuration of a control system of the exposure apparatus in a second embodiment.

[FIG. 12] FIG. 12 is a planar view showing a wafer stage unit related to the second embodiment.

5 [FIG. 13] FIGS. 13(A) and 13(B) are views (No. 1) for describing a drive method of two wafer stages in a parallel processing operation related to the second embodiment.

10 [FIG. 14] FIGS. 14(A) and 14(B) are views (No. 2) for describing a drive method of two wafer stages in a parallel processing operation related to the second embodiment.

[FIG. 15] FIGS. 15(A) and 15(B) are views (No. 3) for describing a drive method of two wafer stages in a parallel processing operation related to the second embodiment.

15 [FIG. 16] FIG. 16 is a planar view showing a wafer stage unit related to a third embodiment.

[FIG. 17] FIGS. 17(A) and 17(B) are views (No. 1) for describing a drive method of two wafer stages in a parallel processing operation related to the third embodiment.

20 [FIG. 18] FIGS. 18(A) and 18(B) are views (No. 2) for describing a drive method of two wafer stages in a parallel processing operation related to the third embodiment.

[FIG. 19] FIGS. 19(A) to 19(C) are views for describing a modified example of a suppressing member.

25 [FIG. 20] FIG. 20 is a flowchart used to explain a device manufacturing method related to the present invention.

[FIG. 21] FIG. 21 is a flowchart showing a concrete example related to step 204 in FIG. 20.

[Explanation of Reference Numerals]**[0237]**

20	main controller (a part of the stage drive system,
5	a part of the switching unit)
80 to 87	wafer stage drive section (a part of the stage drive system)
124	wafer stage drive section (a part of the stage drive system)
10 124A	wafer stage drive section (a part of the stage drive system)
136Y ₁ to 136Y ₄	Y-axis linear motors (a part of the switching unit)
195	a first connecting mechanism
15	(a part of the switching unit)
196	a second connecting mechanism (a part of the switching unit)
ALG1	alignment system (a first mark detection system)
20 ALG2	alignment system (a second mark detection system)
IL	illumination light (energy beam)
Lq	water (liquid)
MST	measurement stage (a second stage)
25 PL	projection optical system
W	wafer (substrate)
WST1, WST1', WST	wafer stage (a first stage)
WST2, WST2'	wafer stage (a second stage)

[DOCUMENT NAME] ABSTRACT**[ABSTRACT]**

[PROBLEMS TO BE SOLVED] Improving throughput, and also preventing water marks from being generated on an optical
5 member on the image-plane side of a projection optical system.

[RESOLVING MEANS] When a transition from a first state where one stage WST1 (or WST2) is positioned at a first area directly below projection optical system PL to which liquid Lq is supplied to a state where the other stage WST2 (or WST1) is
10 positioned at the first area, both stages are simultaneously driven while a state where both stages are close together in the X-axis direction is maintained. Therefore, it becomes possible to make a transition from the first state to the second state in a state where liquid is supplied in the space between
15 the projection optical system and the specific stage directly under the projection optical system. Accordingly, the time from the completion of exposure operation on one stage side until the exposure operation begins on the other stage side can be reduced. Further, the liquid constantly exists on the
20 image-plane side of the projection optical system.

[CHOSEN DRAWING] FIG. 1

Fig. 1

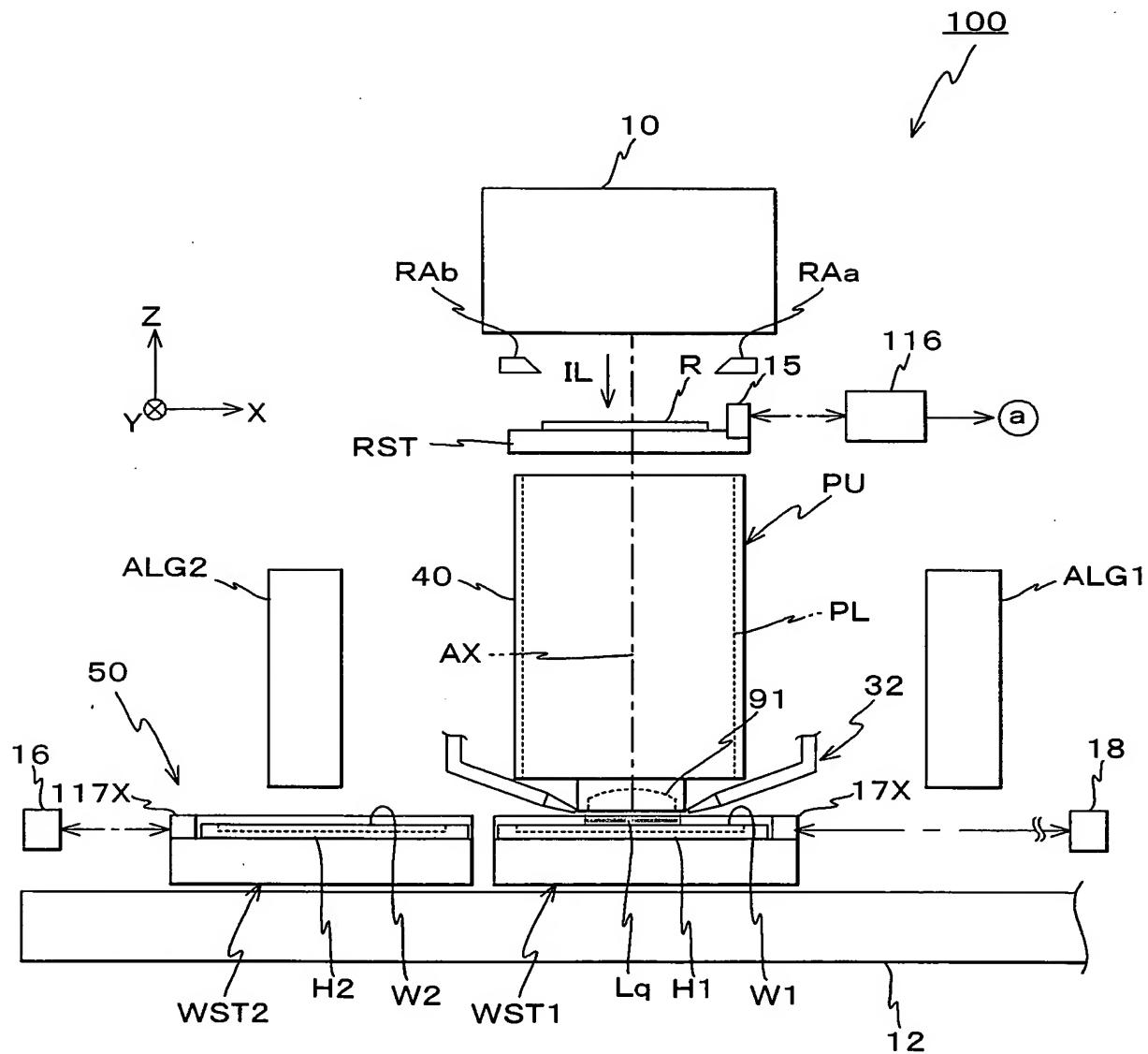


Fig.2

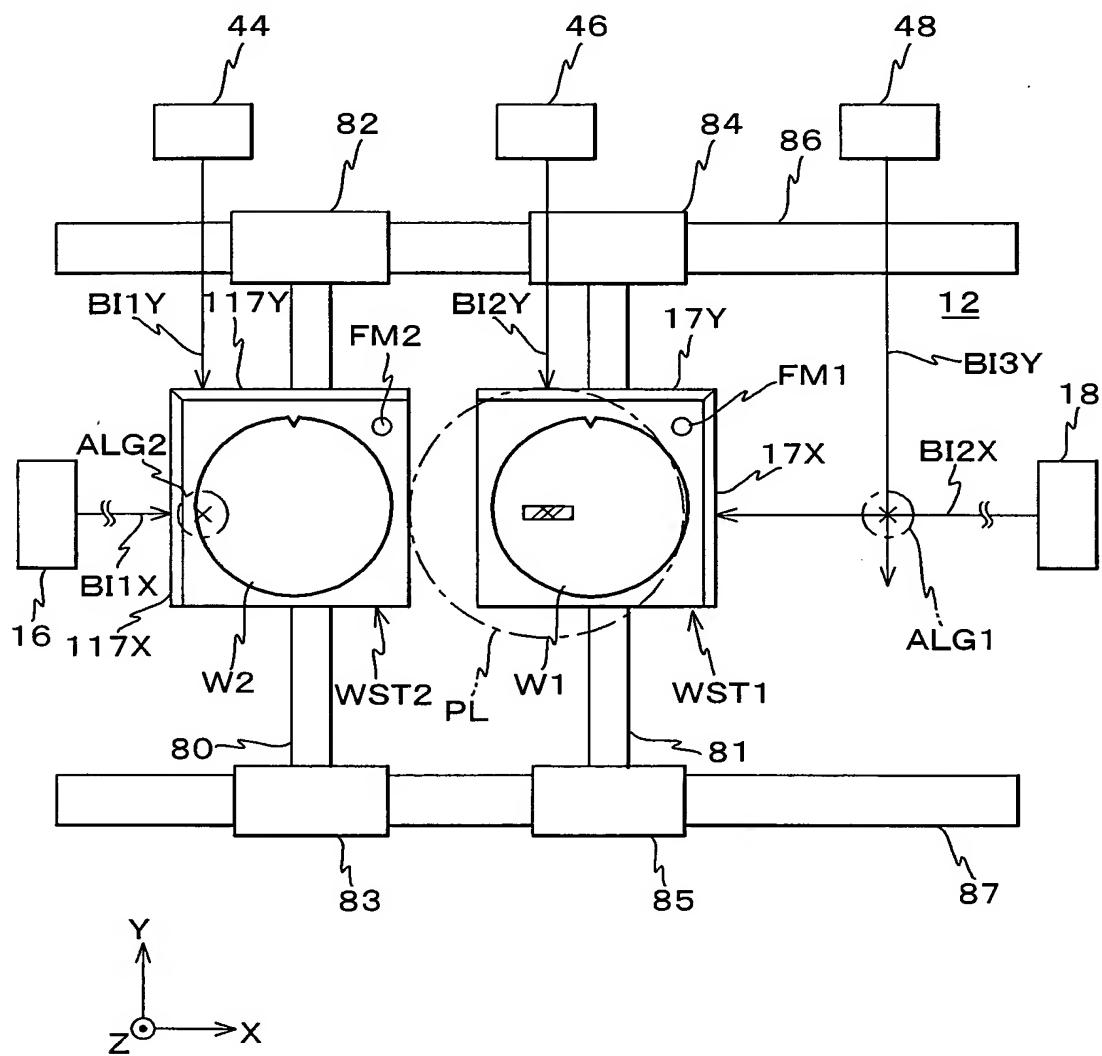


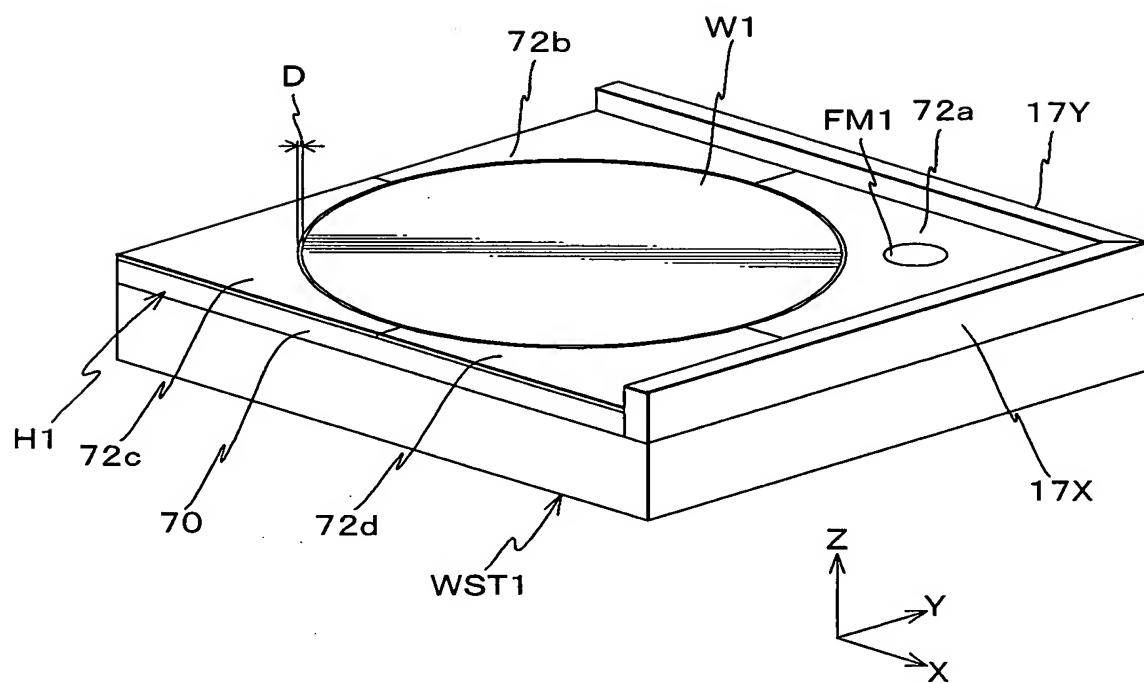
Fig.3

Fig.4

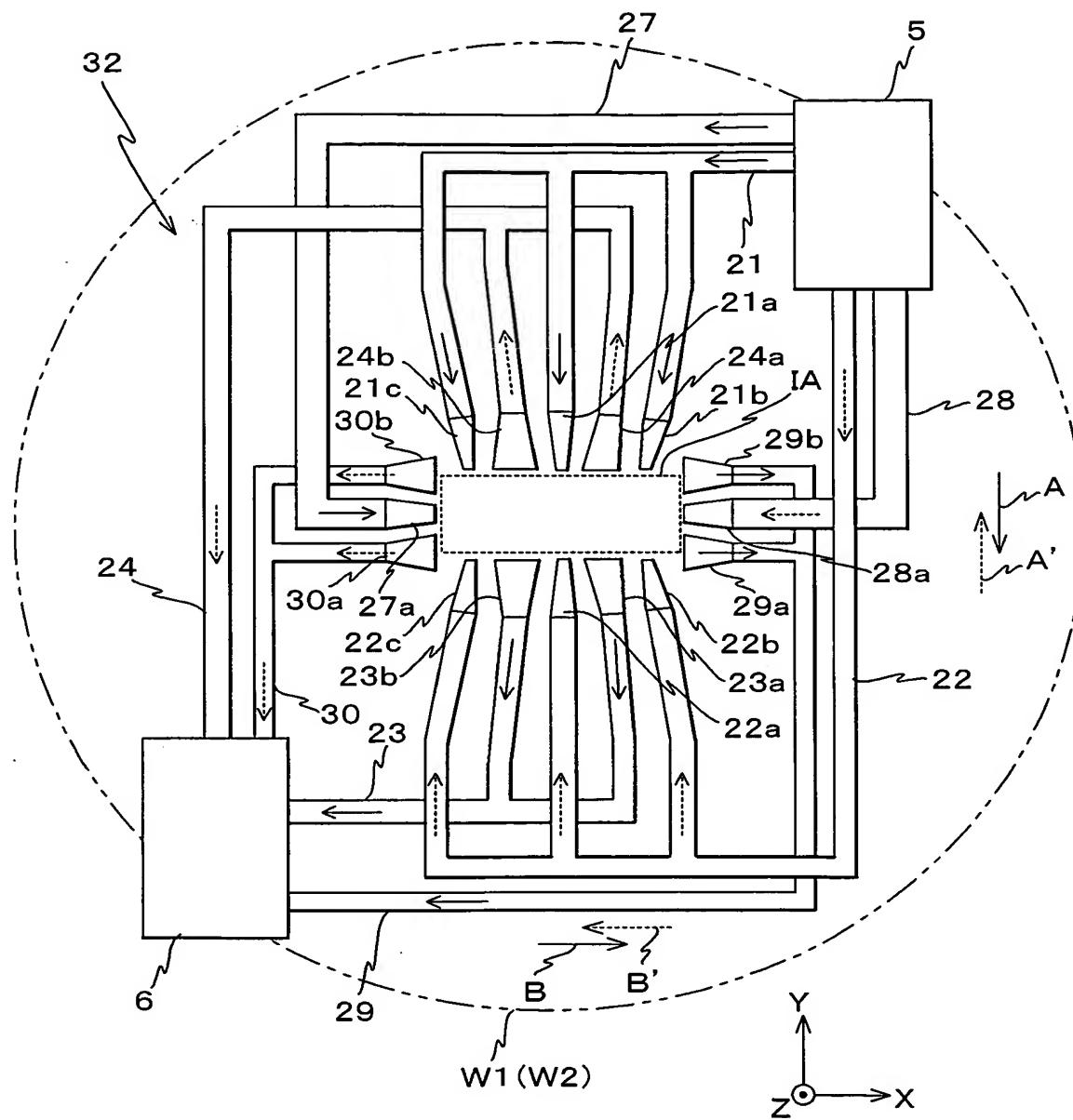


Fig.5

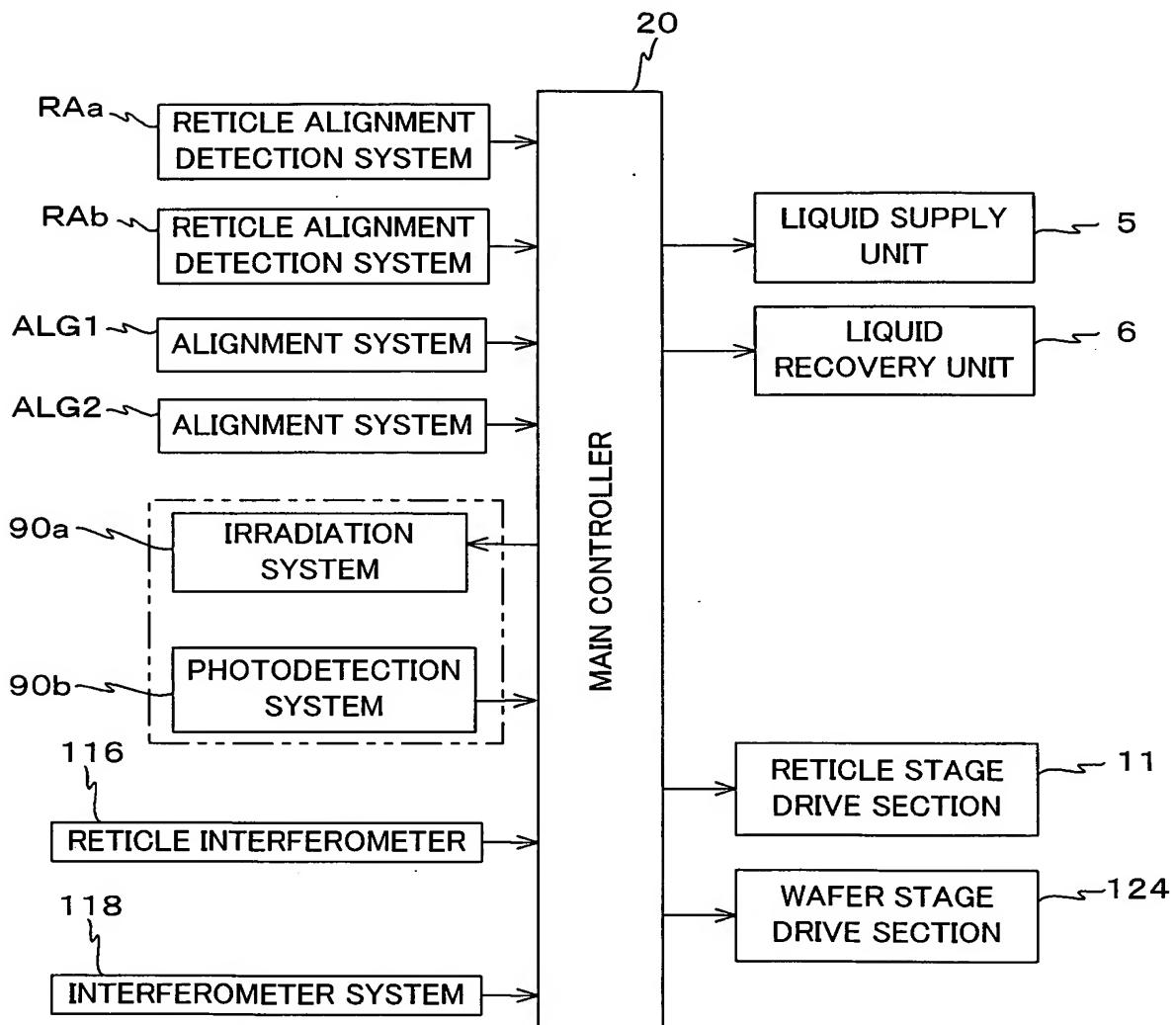


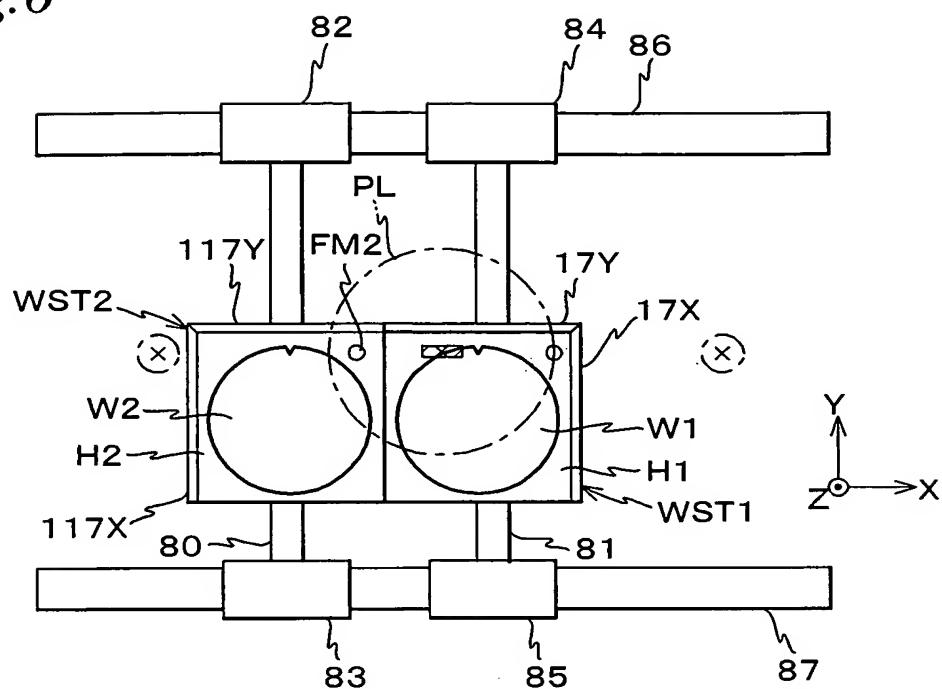
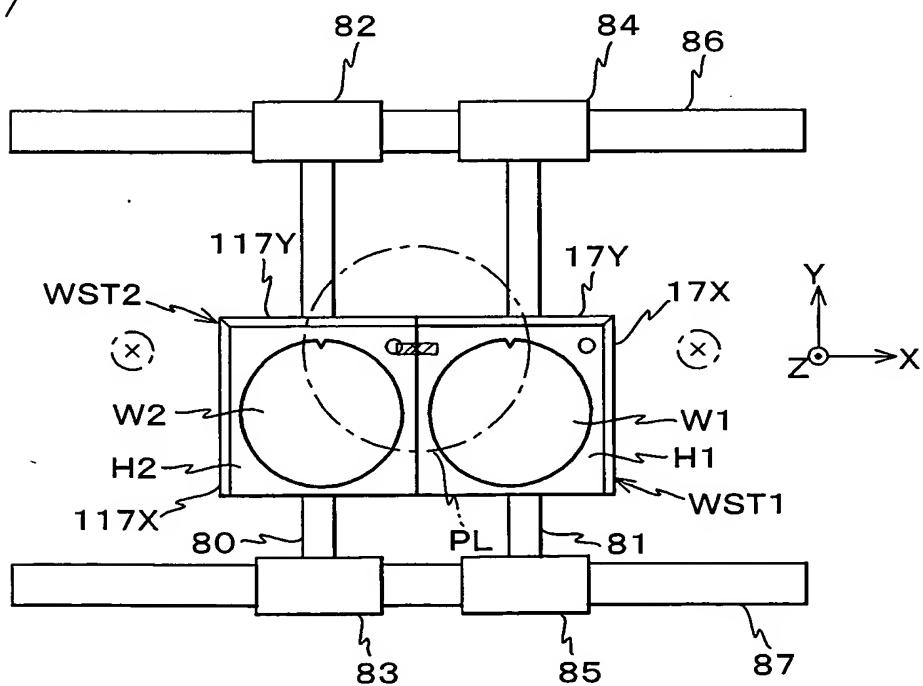
Fig. 6*Fig. 7*

Fig.8

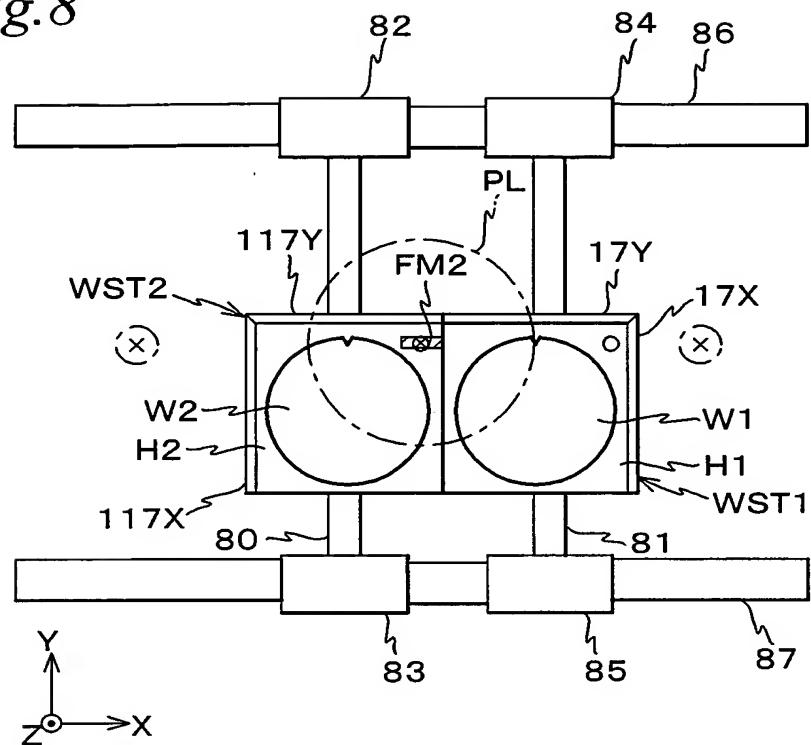


Fig.9

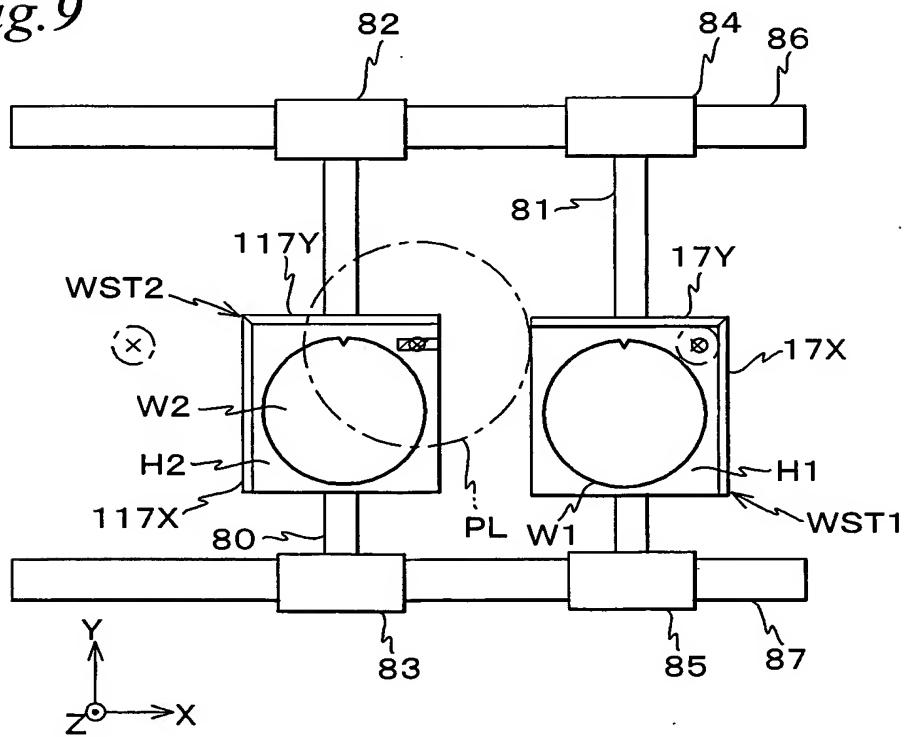


Fig.10

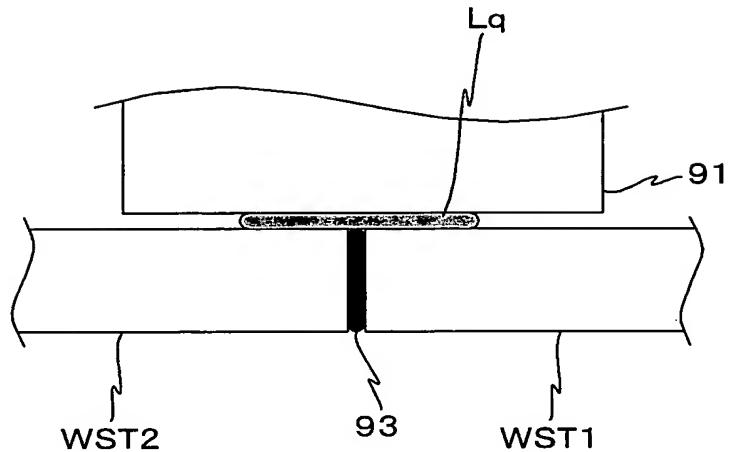


Fig.11

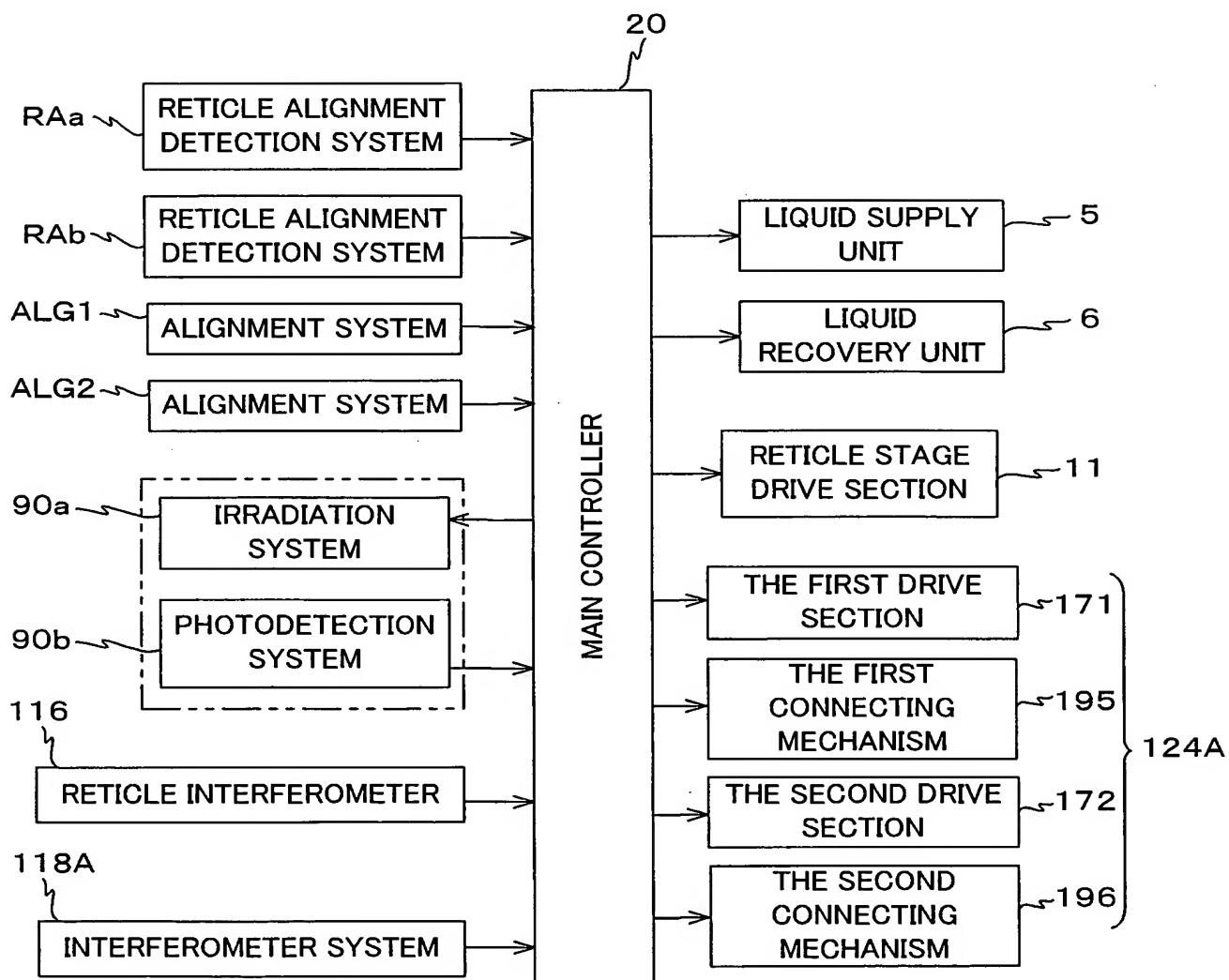


Fig. 12

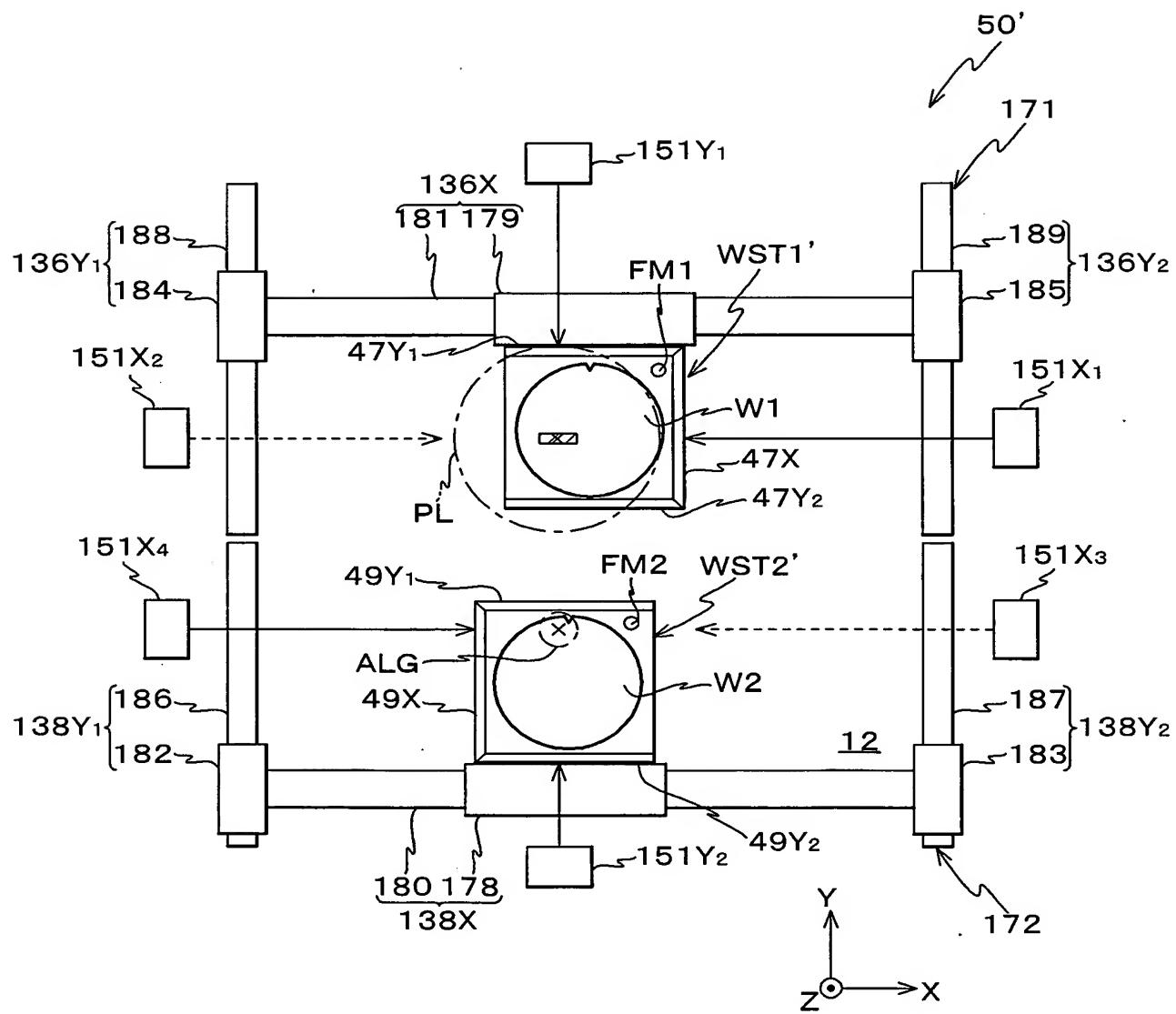
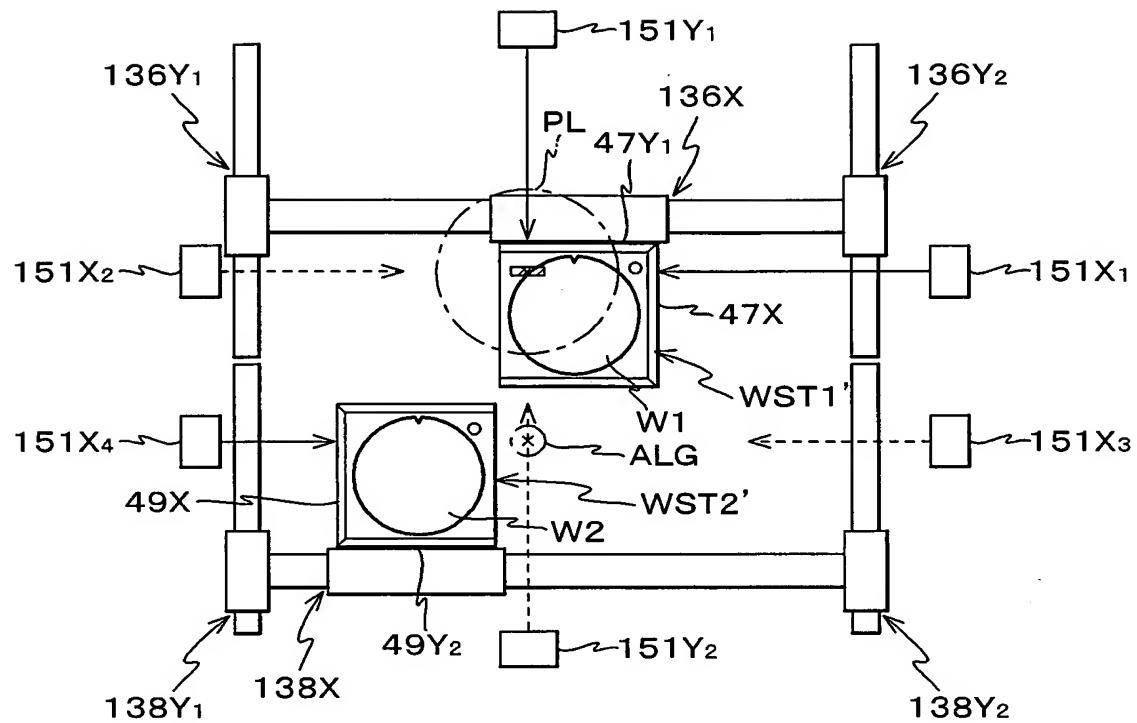


Fig.13

(A)



(B)

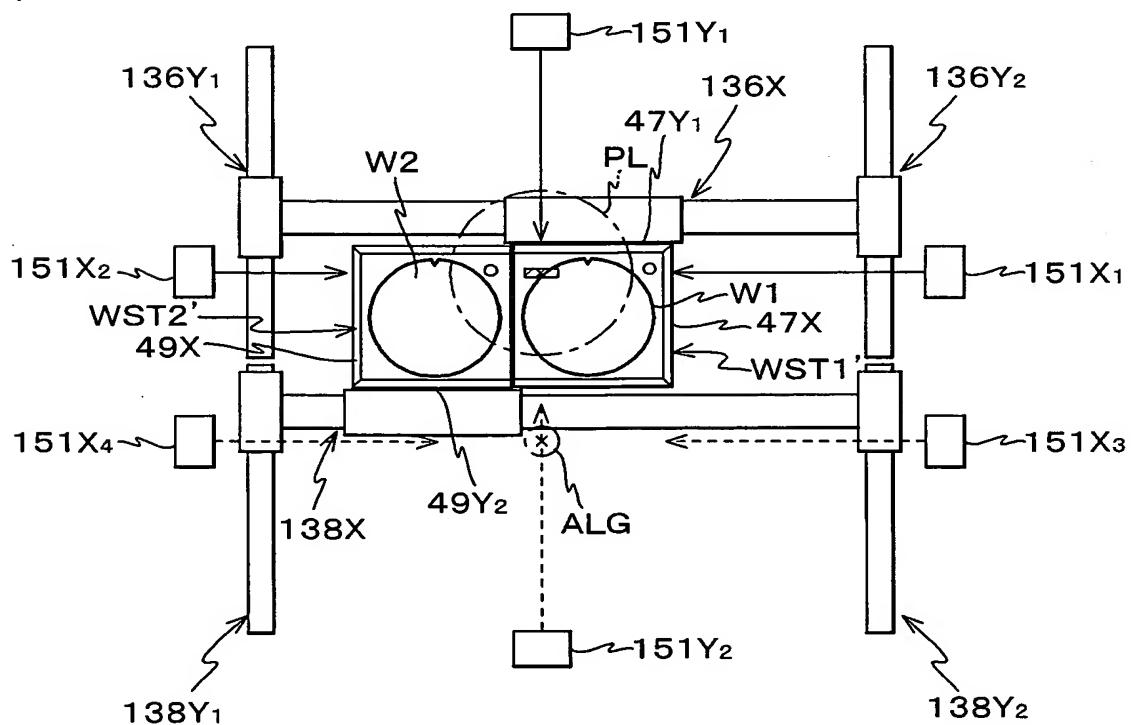
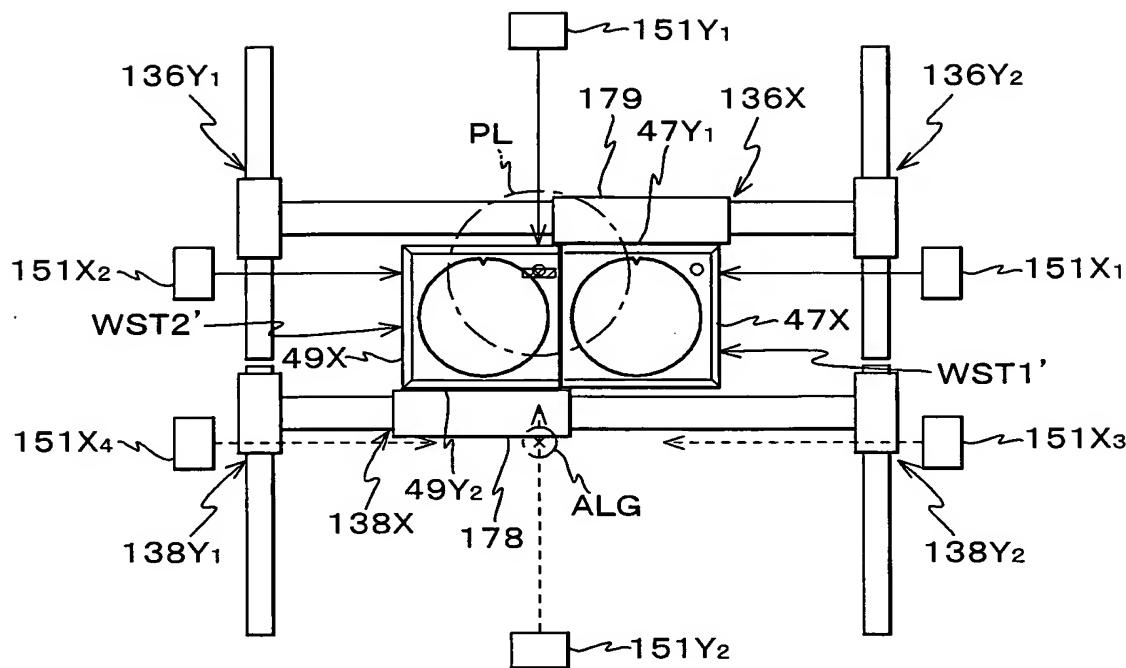


Fig.14

(A)



(B)

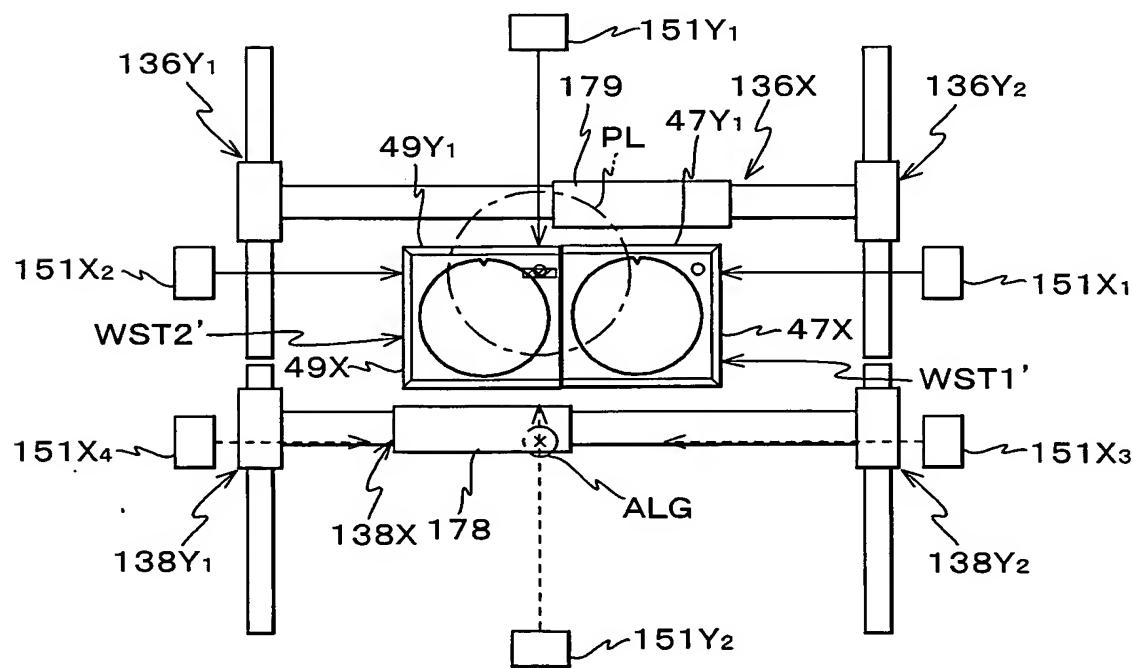
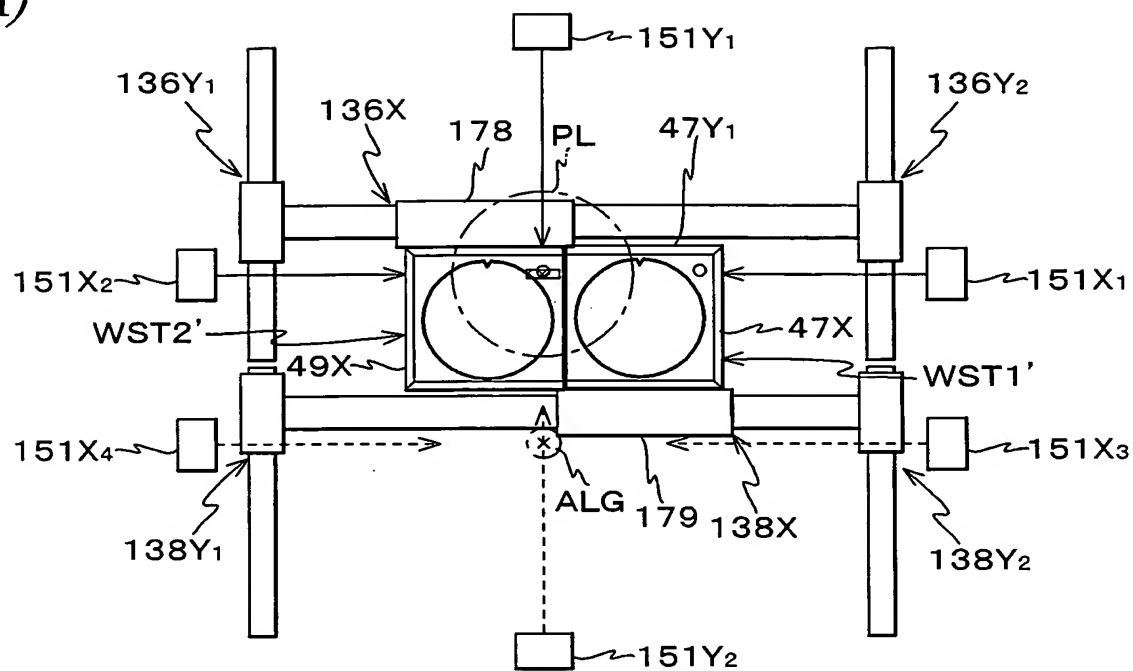


Fig.15

(A)



(B)

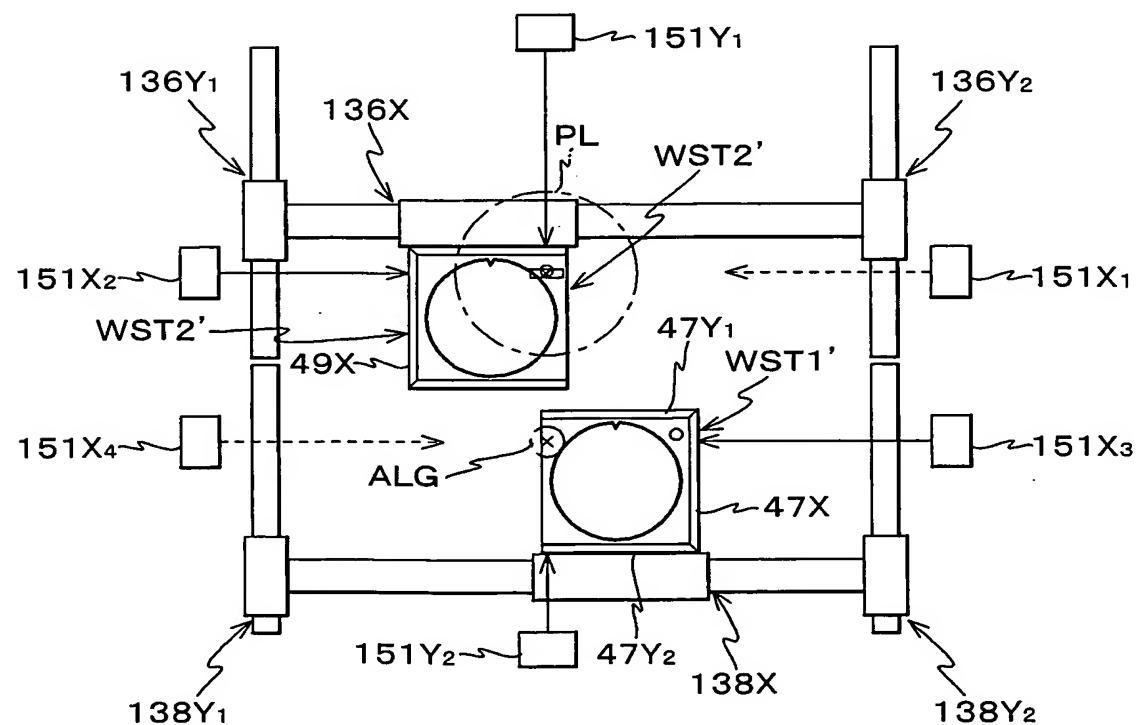


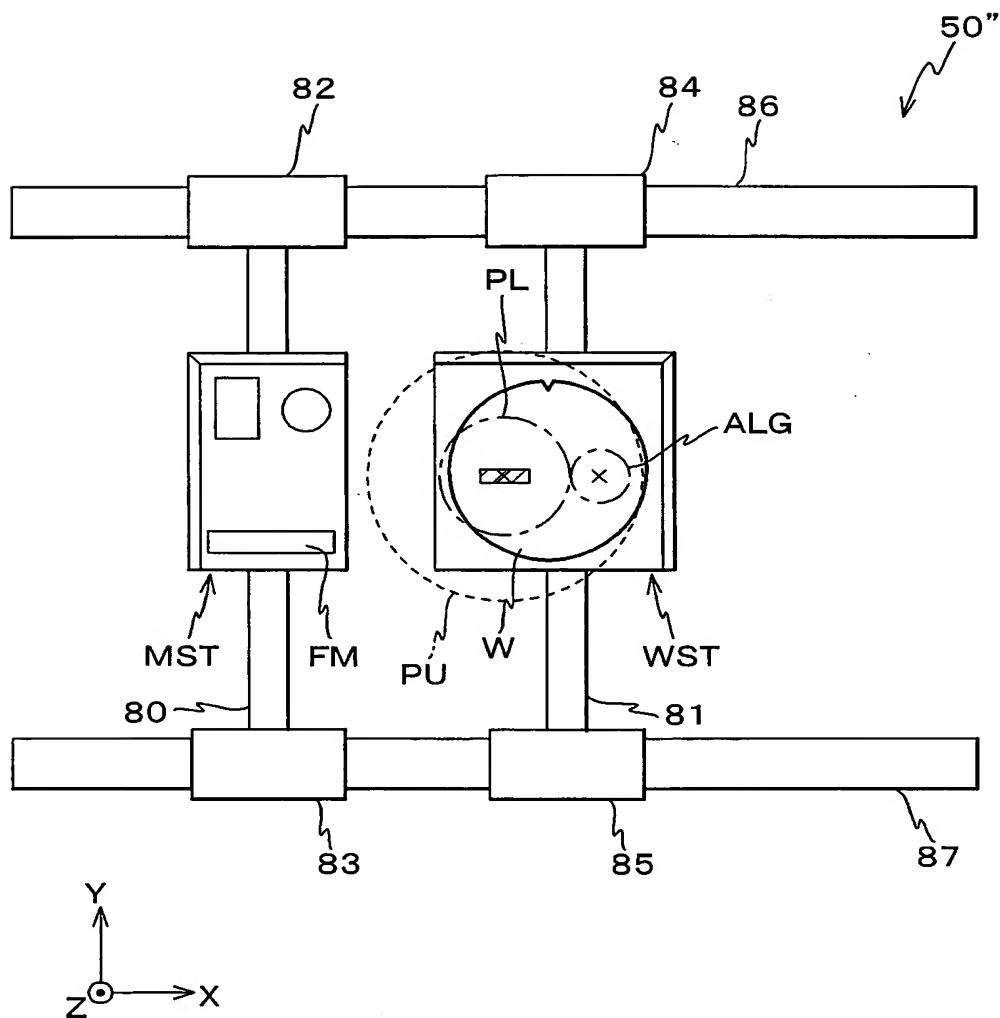
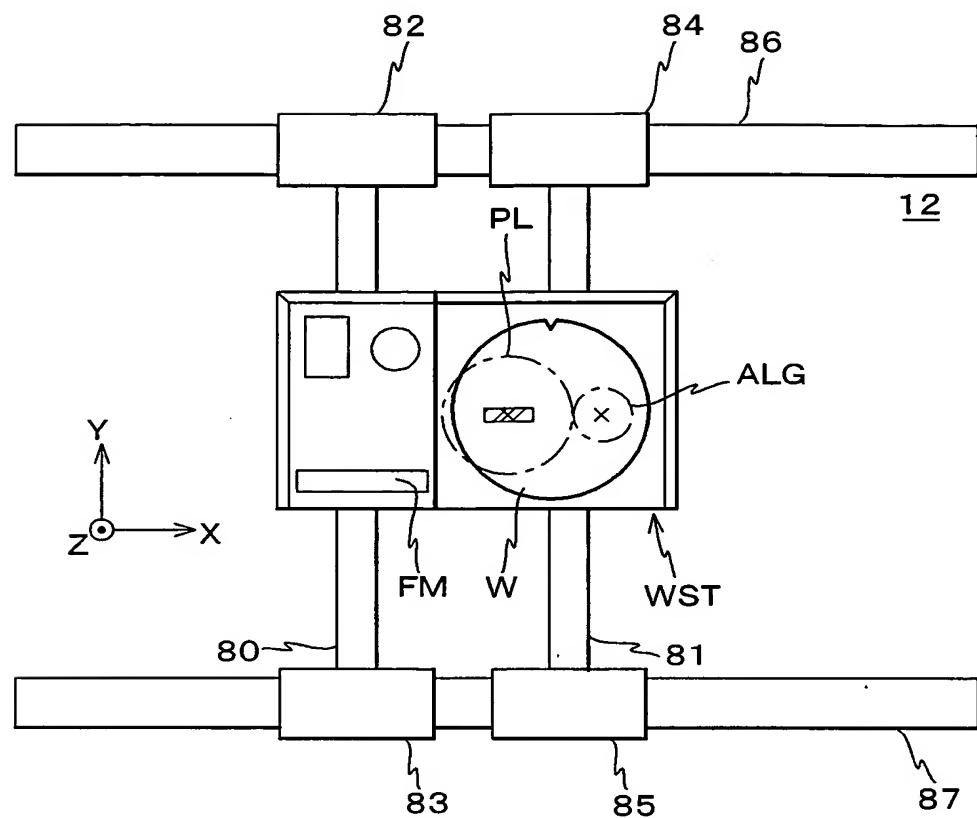
Fig. 16

Fig.17

14/18

(A)



(B)

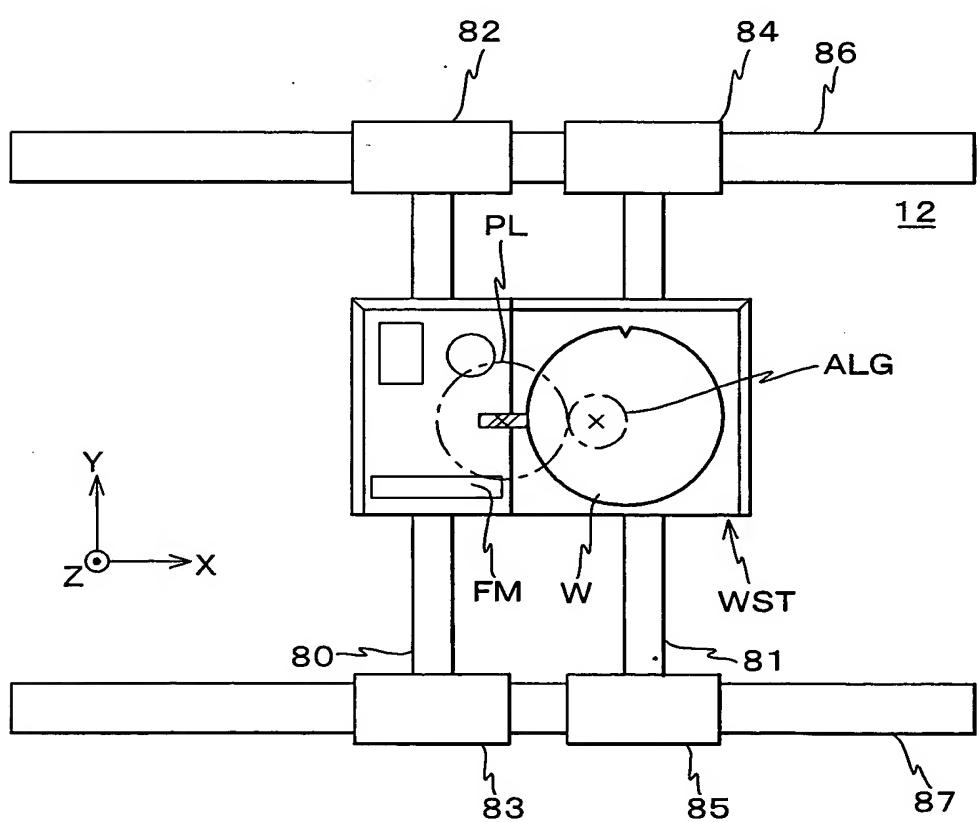
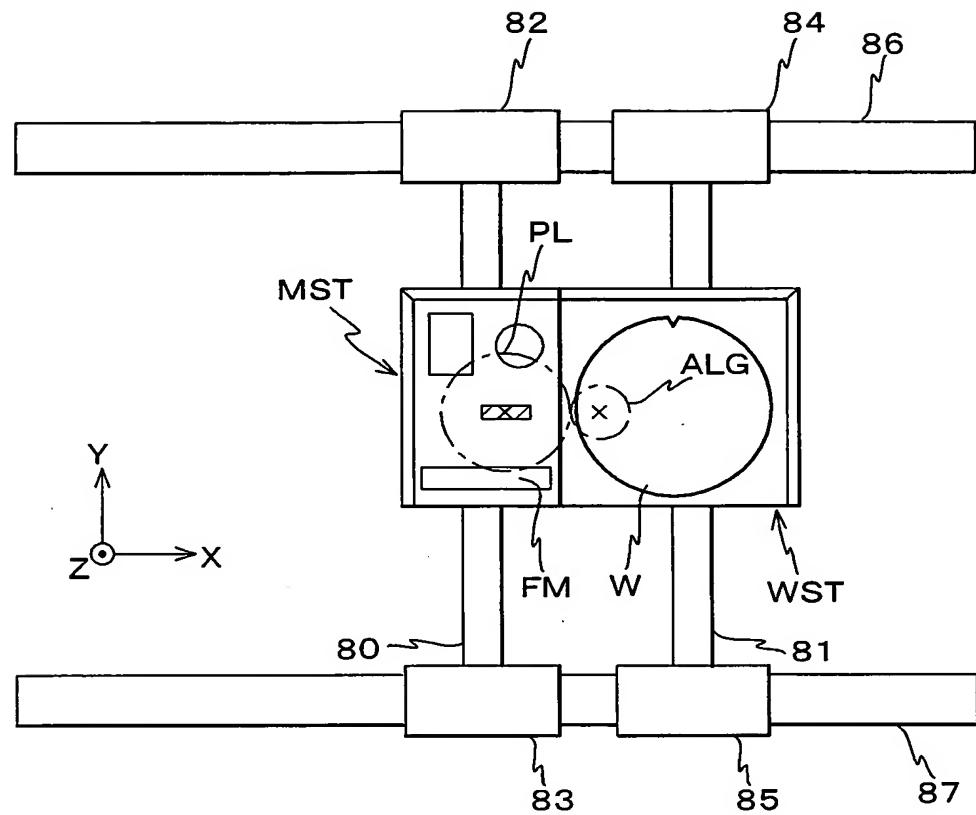


Fig. 18

(A)



(B)

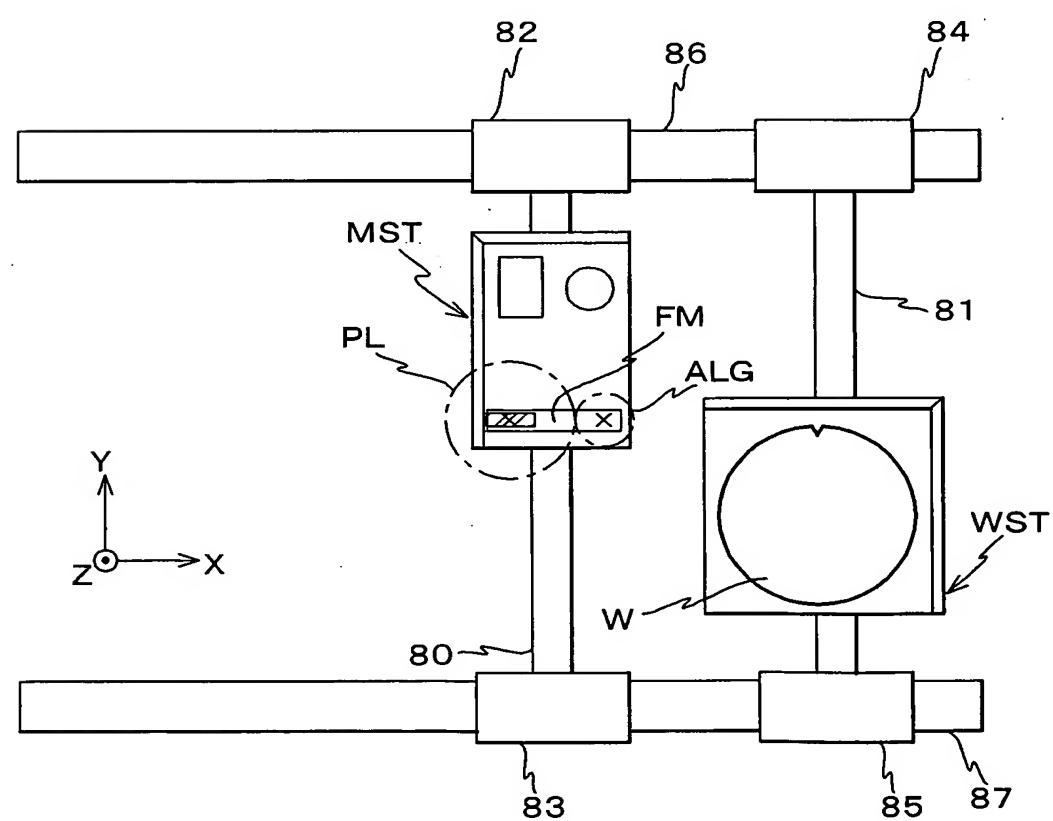
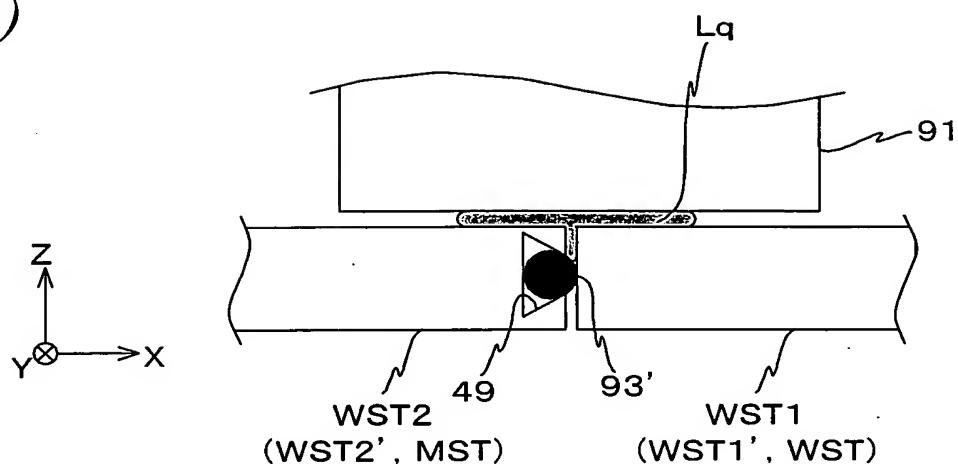
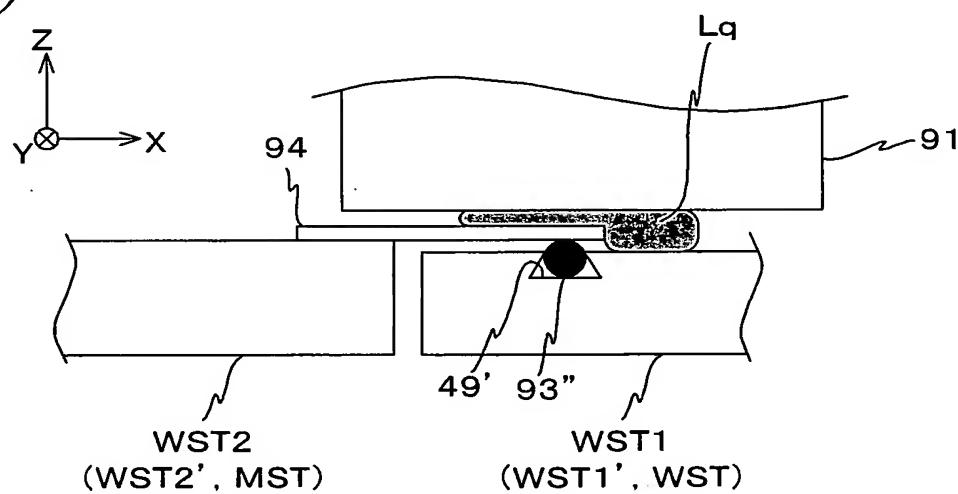


Fig. 19

(A)



(B)



(C)

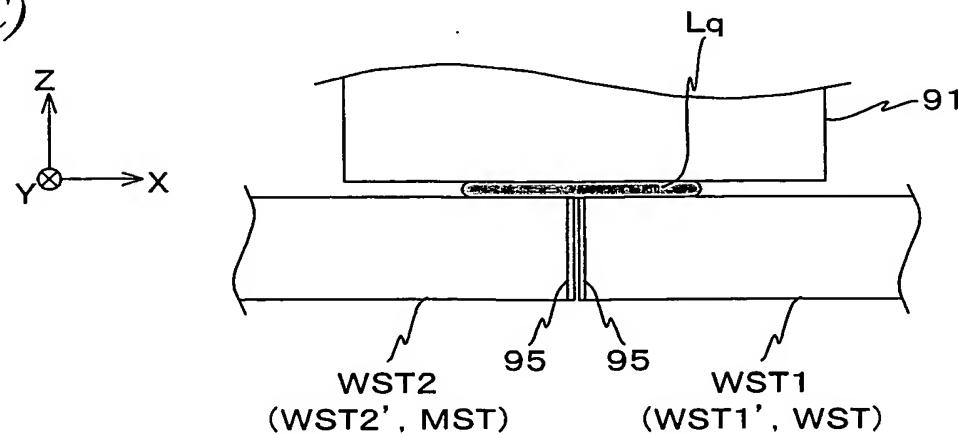


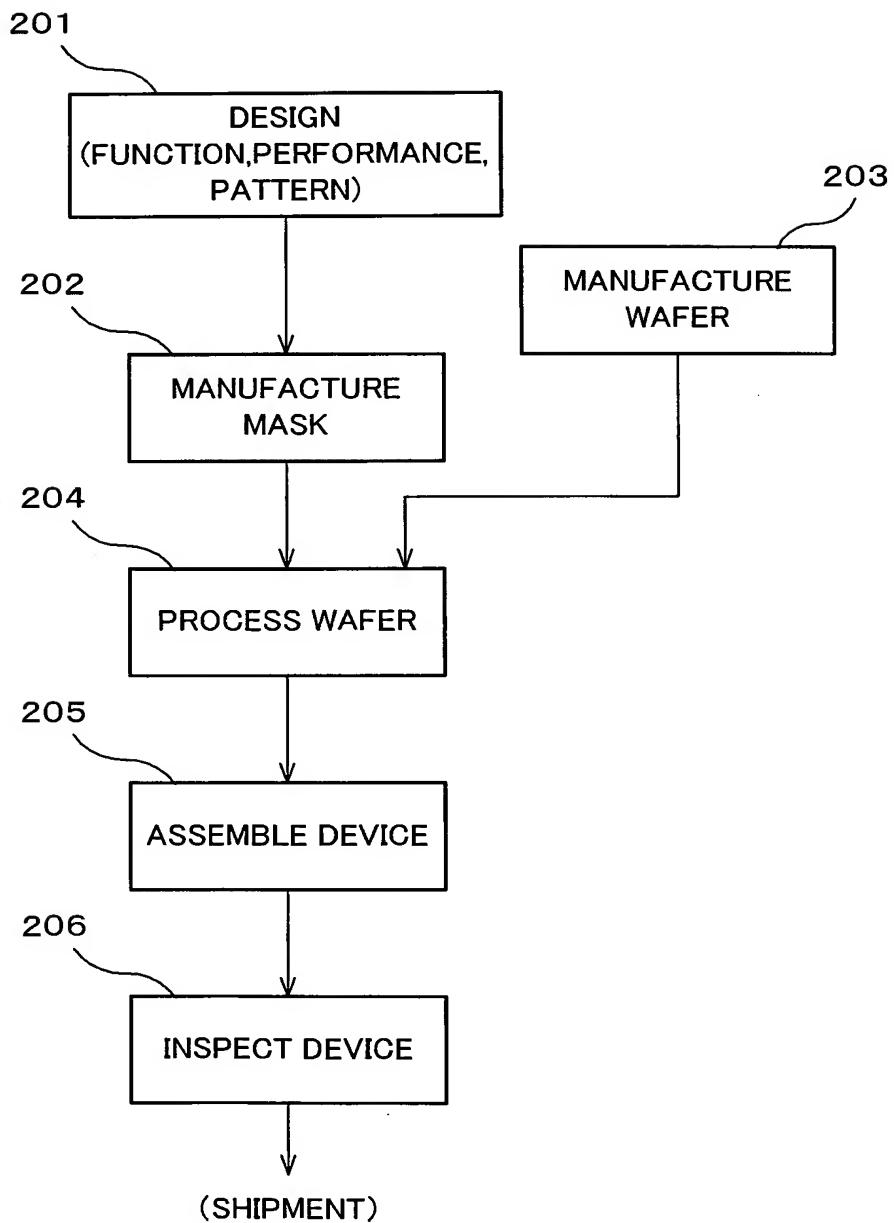
Fig.20

Fig.21

